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Rock&Gem

THE EARTH'S TREASURES • MINERALS AND JEWELRY

The Fight For FOSSILS

SEASCAPES

What once was a vast Devonian sea now provides a resting place for fossilized horn coral and Hexagonaria—and a hunting ground for collectors.

COVER: If you made a rare fossil discovery, like the ammonite, bacculite, turretilla, shark's tooth and 20 million-year-old crab shown here, would you nobly surrender it to science? (Photo by Earl Lewis.)

Rock&Gem

Volume 30, Number 9

September 2000

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And Fossils

A Devonian Wonderland In Michigan's Lower Peninsula

by Kenneth H. Rohn

As I write this, sitting in my camper, I have the most beautiful view from my window. Lake Huron, in all its sun-drenched splendor, is a gigantic panorama before me. I'm parked at a wayside table, right next to the beach. Off in the vast distance, on the horizon, sky meets water as one. I'm here in the Lower Peninsula of Michigan to do some beachcombing—that is, a special kind of beachcombing: searching for and collecting invertebrate fossils.

In my travels to reach this fantastic place during the past week, I've visited three of our Great Lakes. My wanderings have taken me within sight of the south shore of the largest, Lake Superior, while driving through Minnesota and Wisconsin. I also had the impressive experience of viewing both Lake Michigan and Huron simultaneously while crossing the big green bridge with the beige towers. Mackinac Bridge spans the Straits of Mackinac, from the town of St. Ignace on the northern to Mackinaw City at the southern end.

Once, not too many years ago (I remember it distinctly), the only means of getting across was by ferry. At that time, it was a very remote piece of real estate. Today, it's only a few minutes' drive over this huge bridge to either side, and we get one grand view along the way.

The Mackinac Bridge rivals the Golden Gate Bridge for size, length and similarity of construction. Both have cable suspension. At 7,400 feet long, the Mackinac is longer overall than the Golden Gate.

Michigan is the only state in the lower 48 that has two individual land masses separated by water. The northern tip of the Lower Peninsula is fantastic invertebrate fossil country. One can find these ancient sea creatures almost anywhere here. There is, of course, a reason for this phenomenon. At one time in the dim, distant past, this entire area, extending over thousands of square miles, was covered by a warm, shallow, inland sea. The earth was much younger then, by upwards of 350 million years, give or take a few dozen millennia.

The conditions in that warm Devonian sea were ideal for the propagation of vast colonies of diverse species of sea creatures, including coral. Coral beds extend over the entire northern tip of the Lower Peninsula, covering several counties.

Over an amount of time that the human mind has trouble contemplating, the earth began to change. The climate changed dramatically. The tectonic plates of yet-unformed continents were being thrust apart by internal pressures. Probably during this time, or sometime afterward, these coral colonies began to die off. Their remains were eventually covered with an enormous amount of silt, mud and debris, due to the violence of those times. When conditions were right, the process of petrifaction began. These creatures were often duplicated cell by cell, right down to the minutest details, even to coloration. This coloration differs from the host rock in most cases, but this isn't a cut-and-dried rule.

What we find today are the remains of these sea creatures preserved in calcite. Of course, as one might suspect, not all fossil specimens we find here are perfectly duplicated. Mother Nature, in her fickle ways, somehow failed on many occasions to complete the job, and we find a good number of incomplete specimens. Many of these are too soft and porous to cut or polish, and they are quite fragile. On the other hand, the good ones—that is, the harder fossils—can take a high-gloss polish that rivals the best of chalcedony.

Fossils are found in the Traverse Formation limestone, in rock quarries and any place this formation has been disturbed. This is, of course, why we find specimens lying exposed on coastal beaches. They've been extricated from their entombment and washed ashore by wave action and other forces of nature.

These Devonian reef corals are indeed fragile, with only a hardness of 3 on the Mohs scale. Their chemical composition is composed of calcium carbonate ($CaCO_3$) . Therefore, they do not make for very durable gemstones, although their beauty overcomes this deficiency.

Both shores of the northern tip of the Lower Peninsula and several areas in between, including some inland lakes, have produced untold amounts of that pretty calcite replacement of Hexagonaria. To be specific, this is a variety of Prismatophyilium percarnatum—a mouthful.

continued on next page

Seascapes/ *from page 13*

This particular colony coral grew in a hexagonal pattern, with each individual animal packed very tightly next to its neighbors. The body of each has weblike lines radiating from a center core of contrasting color to the body. The center core is often of a dark-brown coloration, while the outer body is usually brownish-gray. The borders of each creature are outlined with an off-white line. You'll often find them in a mass, from a few inches in diameter to more than 8 inches, and sometimes even larger specimens have been found. Each individual animal is from ¼-inch to ⅜-inch in diameter and several inches long. As a rule, fossil fragments much smaller will be found, especially where heavy collecting has taken place.

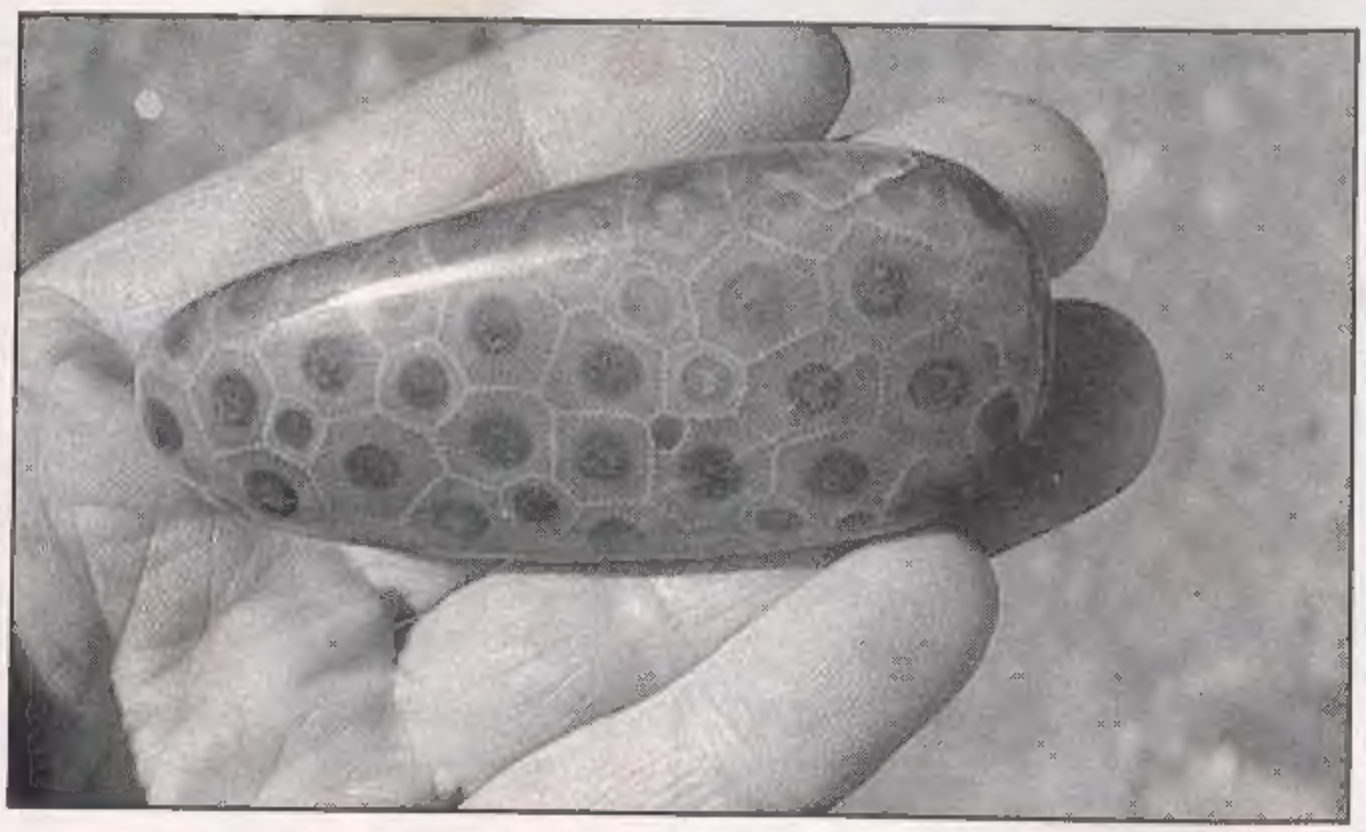
Hexagonaria evidently formed millions upon millions of these colonies and coexisted on the shallow sea floor.

The popular name for this species, and one that is much easier to remember and pronounce by local vernacular, is the Petoskey stone. This name seems to have taken hold and is commonplace today. Some people have gone so far as to call it a Petoskey agate, but the chemical composition of this limestone fossil bears no resemblance to chalcedony whatsoever.

There are a number of other invertebrates to be found here, such as horn coral or cup coral. This is an individual type, so named because of its obvious horn-of-plenty shape, and the concave circular top or head end. Unlike its cousins, chain coral and Hexagonaria, which were extroverts in the extreme and thrived in very close-knit colonies, the horns lived as loners in that vast, ancient sea. Favorsite (chain coral), of course, bears its nickname due to the chain-like structure of these creatures. Also found here are Stromatoporoids and Bryozoans, corallike organisms. Crinoid fragments, such as stems and parts, are found on occasion. I didn't find any on this trip. Usually, only stem sections are recovered. These were bottom-dwelling, flowerlike carnivores with very large flowering heads, and unusually long and slender stems. Brachiopods are found here and there. Many are imbedded so tightly in the limestone matrix that I found them almost impossible to extricate without totally destroying them. (One wrong blow of the hammer often does just that.) They are here, but often hidden inside limestone nodules, and usually of the same consistency and color as the host rock.

There's a tightly cemented conglomerate found here that is called pudding stone by the locals because of its resemblance to pudding with raisins throughout. The color of this stone varies. I have a slab that has been cut and drilled for a clock face, and it has a grayish body with brownish-red lumps the size of raisins imbedded in it. I found a water-worn piece on the Huron beach, and saved it purely for a cabinet specimen. I'm told that large masses of this stone have been quarried for bookends and other decorative pieces, even small tabletops and building material. It's a most handsome stone.

After crossing the Mackinac Bridge, my first stop heading south was the city of Petoskey. This bustling community, situated on the shore of Little Traverse Bay off Lake Michigan, is reached via U.S. Highway 31. The waterfront park, which covers several city blocks in length, has been a favorite collecting site for as long as anyone can remember, probably going as far back as the time of Chief Petoskey himself. Although fossils are not as plentiful as they once were, new, fresh specimens washed up from deep water are being found after each violent storm. Finding them takes an eye trained in knowing just what to look for. As can be expected, the beach at Petoskey is littered with tons upon tons of rocks of all sizes and shapes, and almost all of them have that same gray coloration. Careful searching and patience pays off every time. It cannot be rushed if one expects to find good specimens.



A polished specimen of Hexagonaria, popularly known as Petoskey stone, shows the distinct pattern of each animal and their tight-knit structure.

According to research on the subject, with only a few exceptions, all varieties mentioned above can be found in a number of locations in the following counties: Emmett (Petoskey is situated in this county), Alpena, Cheboygan, Presque Isle, Antrim and Charlevoix. This includes the area from Little Traverse Bay on the Lake Michigan side all the way to Alpena on the Lake Huron side. This is lot of territory to search in.

I had my best luck in Presque Isle County, north of Rogers City, along U.S. Highway 23. There are several places to park off the highway all along the lakeshore as you drive north. Some areas also have a picnic table on or near the beach.

This vast expanse of beach is sometimes interrupted by private property. These areas are, of course, to be avoided, unless permission is granted by the owners. Maybe the good will generated by showing respect for private property will help keep our hobby strong.

The beaches I searched on Lake Huron are wonderfully littered with pebbles, an occasional larger rock and large amounts of driftwood. It's in complete contrast with the Lake Michigan beaches in this latitude. The Huron beaches are underlain with soft, pink sand, with most pebbles and rocks lying on the surface. In my book, it's an ideal collecting situation.

Although I didn't check out Burt Lake and Otsego Lake, farther south, they could prove very fruitful. It has been my experience so many times that, wherever there's an inland lake in this country, there's also private property blocking public access, so I usually don't do much investigating there. But believe me, there are plenty of miles of beaches here, and it would take a great deal of time to walk them all. On this field trip, I only covered a very tiny fraction of these sites.

I didn't search in any gravel pits, but they, too, could prove very lucrative, if the owners can be located and permission granted. For what it's worth, I discovered that the Lake Michigan beaches consist primarily of the species Hexagonaria, with an occasional brachiopod recovered. The Lake Huron beaches, on the other hand, are littered with predominantly horn corals. (At least, this is the way I found them.) I discovered some here that are perfectly formed in their entirety, and about the size of a thumbnail. I found another one that was in complete contrast. Its water-worn shape belies its original size, but it must have been 2 to 3 inches in diameter when alive, and there's no clue as to how long it actually was, due to erosion.

continued on next page

Seascapes/ *from page 15*

This area is vast. You could spend days, possibly weeks, walking just one area of beach, if you were to search systematically. One could easily, without exaggeration, fill a car trunk to overflowing with fossils. I found no rules or regulations—except, of course, at state parks and other government sites, which are off-limits to collecting—on just how much could be collected. However, I would say, let prudence and common sense be our guide. Let's save some for the ones who come after us.

As I mentioned earlier, fresh material is being washed ashore as time passes. As a matter of fact, I witnessed a specimen being tossed about in the shallows not 6 feet away. It looked inviting, so I stepped out into ankle-deep water and retrieved it. It actually happened to be one of the better specimens of horn coral that I found on the trip. In all probability, I was the first human ever to see it.

This north country has a variety of accommodations for any budget. Campgrounds are plentiful, if that's your cup of tea. Motels, hotels and bed-and-breakfast inns also abound here. In my case, my camper serves me well, and I have the opportunity to sleep in my own bed each night while on the road.

The weather in spring can be changeable. A cold front can move in and chill things down considerably. The Great Lakes have a strong influence on the weather here. A variety of cool-weather clothing is in order. Summers can get hot and sometimes humid, but you are never far away from those natural air conditioners, the Great Lakes. They help keep the temperature moderate, even on the hottest days.

A word of advice: Do not get caught out on any beach or meadow during a thunderstorm. These storms blow in quite suddenly at times, and as we outdoor people know, or should know, lightning tends to seek out the highest point near ground. If you happen to be the highest point, you could be in grave danger. So take proper precautions, and take shelter away from any lone-standing trees in the area. Play it safe. As in any hobby or sport, rockhounding is only as safe as we make it. For me, it is one of the most rewarding of outdoor activities.

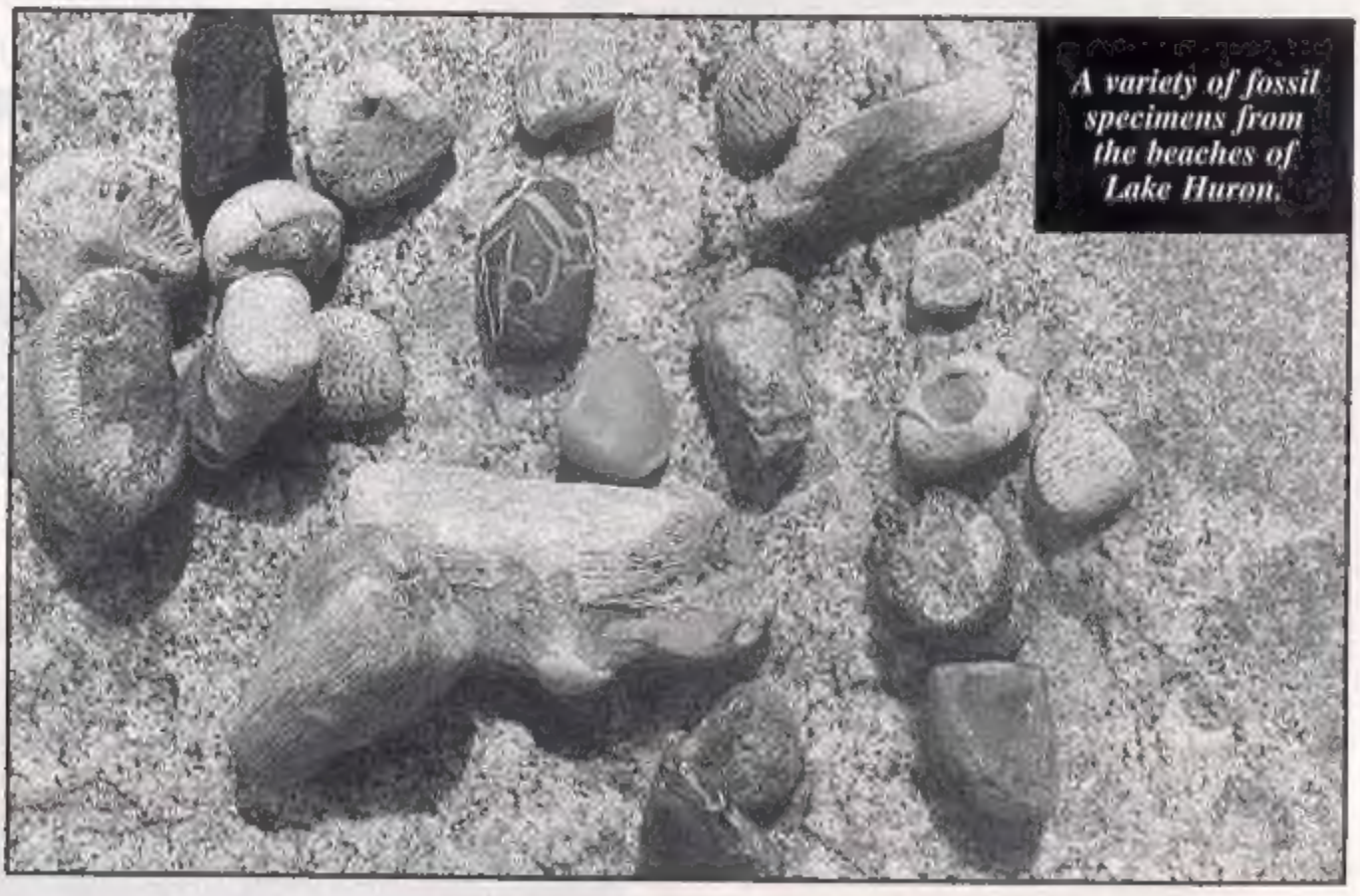
The highways in this country are very good to excellent. Even the secondary roads that may be encountered are in good shape. I had no trouble wheeling my big camper around, although as everywhere else, drivers are in a hurry to get around you.

Interstate 75, which traverses the entire length of the state from north to south, is a very good highway, and it's an excellent way to reach the area from either direction.

If you grow tired of trudging the beaches, a great diversion and a wonderful addition to this field trip is a ferry ride to Mackinac Island State Park, situated five miles out from the mainland, in the Straits of Mackinac. One unique feature of this historic island is the fact that no autos are allowed here. Horse-drawn carriages and bicycles are the only means of getting about. I took the trip and spent a most enjoyable day there. I rode my mountain bike all around the island on State Road 185, which is about a 10-mile ride, all along the shoreline of Lake Huron. The scenery is spectacular.

This island is a photographer's paradise, with rustic, historic buildings everywhere one looks, that are perfectly restored. Flower gardens, beaches, hillside mansions and dense forests all beg to be photographed. It was a most exciting and unusual experience to ride on the large, high-speed catamaran to and from the island.

If you desire to seek out a variety of invertebrate fossils, you, too, can experience the thrill of discovery and have a great time of it in the bargain. So why not set your sights on Michigan's Lower Peninsula? You will be rewarded tenfold.



A variety of fossil specimens from the beaches of Lake Huron.

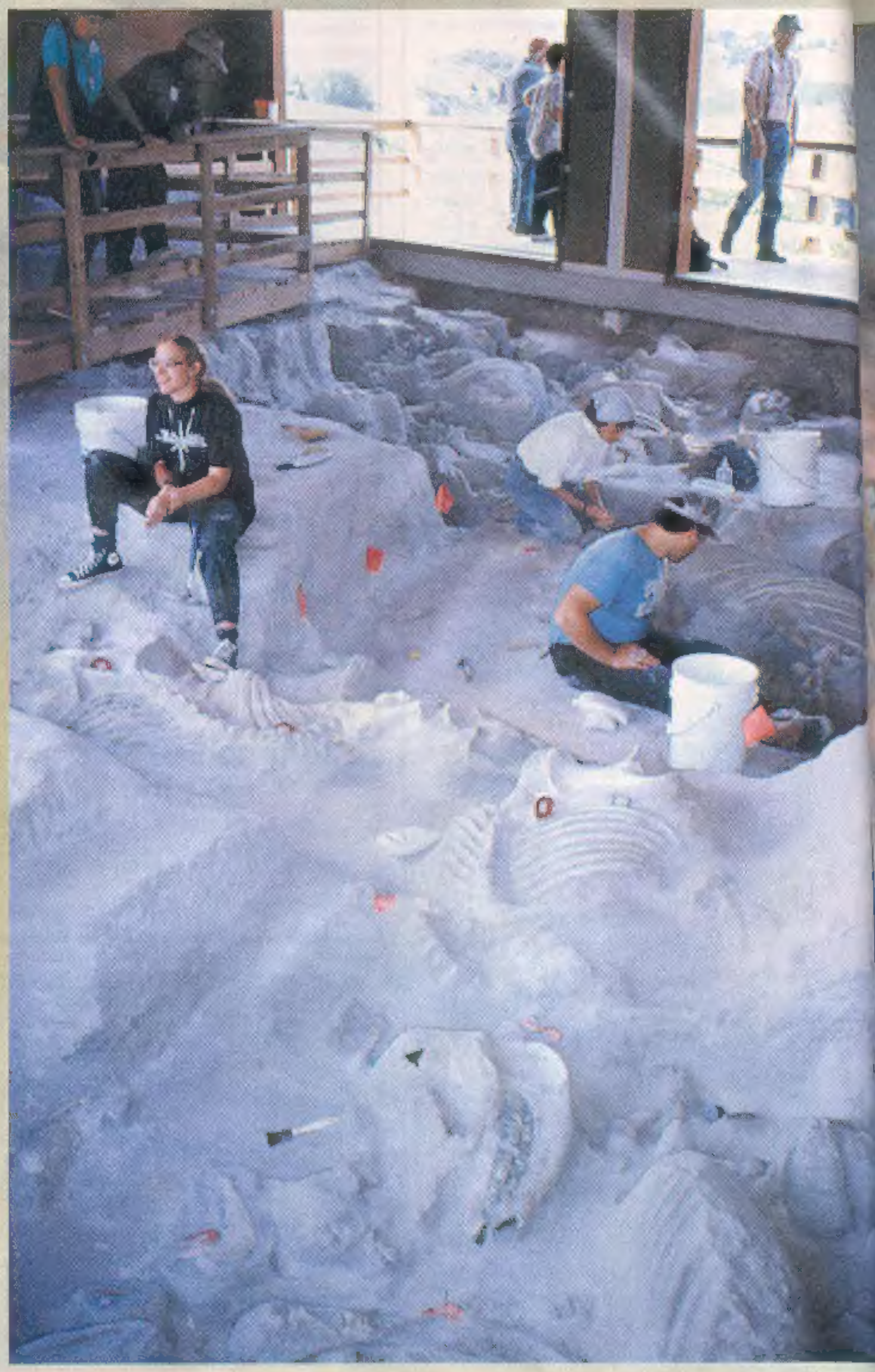
THE Fossils

A Paleontologist's Dream Site Yields Major Finds

by Steve Voynick

Paleontology has never been an easy job, largely because the fossil remains of ancient life—especially those of mammals—tend be fragmentary and rather randomly located. Since most mammals die on land, their carcasses are exposed to scavengers and subject to rapid aerobic decomposition. Accordingly, fossilized mammal remains are relatively rare, and are usually characterized by incomplete skeletons of disarticulated, scattered bones. Although such sites are nevertheless valuable, they make it difficult for paleontologists to determine the characteristics of the original animals, and to gain insight into their behavior and the environment in which they lived.

Were paleontologists to "design" an ideal mammal fossil site, they would want a deposit that contained hundreds of skeletons in three-dimensional preservation with the individual bones fully articulated, that is, joined together in the proper order. They would want to find fossilized mammals—including such large animals as two-ton rhinos—literally buried in their tracks, with their last footprints clearly visible. They would want to be able to study ancient mammals in lifelike positions, such as females in nursing positions alongside their offspring, and



OF Ashfall

The fossils of the Ashfall beds provide paleontologists with new revelations about life at a Pliocene prairie water hole. Members of the public observe from walkways over the beds.

others still carrying the bones of unborn young. Perhaps they would even hope for mammal skeletons that contained the fossilized remains of the last mouthfuls of food.

Although such sites are extraordinarily rare, they do indeed exist. One of the world's most spectacular mammal fossil sites is Nebraska's Ashfall Fossil Beds State Historical Park. And the best part is that the public is welcome there. Ashfall Fossil Beds is located in northeastern Nebraska near the tiny towns of Orchard and Royal, about 100 miles west of Sioux Falls, Iowa.

Ashfall Fossil Beds is a remarkable fossil record of life at a prairie water hole in Pliocene times, some 10 million years ago. The park has yielded hundreds of complete, fossilized mammal skeletons, including those of rhinos, horses and camels, as well as reptiles and birds. Visitors can see dramatic displays of complete, fossilized mammal skeletons in the exact locations and positions in which they were uncovered. They can watch and talk with professional paleontological excavators who are continually exposing new skeletons. In short, it's a site that anyone interested in fossils and paleontology should make an effort to see.

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Ashfall/ *from page 21*

The story of Ashfall Fossil Beds began 10 million years ago during the Pliocene Epoch of the Tertiary Period, the first and longest period of the Cenozoic Era. If the preceding Mesozoic (middle life) Era was the "Age of Reptiles," then the Cenozoic (recent life) Era is indeed the "Age of Mammals." Dinosaurs met their extinction at the end of the Mesozoic era, about 65 million years ago, very likely because of a cataclysmic meteoric impact. The subsequent, worldwide environmental modification then gave the evolutionary edge in development and reproduction to mammals.

By Pliocene times, mammals were quite advanced and possessed many of the characteristics of modern species. What is now northeastern Nebraska was then covered with subtropical grasses, and patches of jungle, an environment that paleontologists compare with the present-day savannas of East Africa. The area that is now Ashfall Fossil Beds was then a large water hole that attracted many grassland animals.

Life might have gone on undisturbed at that Pliocene water hole had it not been for enormous volcanic eruptions that occurred more than 1,000 miles away to the west, probably in what is now southwestern Idaho. Dense clouds of fine, dustlike volcanic ash drifted eastward, depositing layers of ash across the Great Plains. In northern Nebraska, the volcanic ash covered the ground to an average depth of about 1 foot. As the light ash accumulated, winds moved it about like drifting snow, sweeping the hilltops and higher ground clear of ash, while filling low-lying areas to depths of more than 8 feet.

The low-lying Pliocene water hole became buried under a thick layer of ash with disastrous consequences for the reptiles, mammals and birds that inhabited the area. Animals by the thousands were either buried outright to suffocate, or died a short time later from the debilitating effects of breathing the ash.

While the deep ash layer spelled death for the local animal population, it also provided near-perfect conditions for preservation of their remains. Carcasses were quickly buried as they fell, and the anaerobic burial environment contributed to subsequent fossilization. Furthermore, the fine grain of the dustlike volcanic ash eventually petrified the skeletons in a manner that would preserve the most delicate details of individual bones.

After the distant volcanic eruptions ceased, normal patterns of geologic deposition resumed, covering the ash with alluvial sediments. In time, those sediments became compacted into a durable sandstone that protected the soft, fossil-rich ash layer for the next 10 million years.

During the relatively recent Pleistocene ice ages, the regional pattern of geologic deposition turned to one of erosion. Pleistocene glaciers scoured away the sandstone layers, exposing many mammal fossils. Northeastern Nebraska, particularly along the Niobrara River near the South Dakota border, became one of North America's richest sources of Miocene and Pliocene mammal fossils. In the late 1800s, paleontologists and commercial bone hunters began excavating the sandstone walls along the Niobrara River and its tributaries, recovering hundreds of mammal fossils that represent North America's most complete record of Tertiary grassland animals. Today, virtually all the world's major natural history museums display fossilized Tertiary mammal skeletons from Nebraska's Niobrara River Valley.

The modern story of Ashfall Fossil Beds began when unusually heavy spring rains fell on northeastern Nebraska in 1971. The rains swept away soil and debris over a wide area, including a gullied hillside on Melvin Colson's farm near the town of Orchard. Although the Colson farm was 20 miles south of the famed Niobrara River fossil sites, it, too, was a known source of fossils. Collectors first found fossils there in the 1920s. And in 1953, a fossil collector found a partial rhino skull embedded in sandstone. Mike Voorhies, curator of vertebrate paleontology at the University of Nebraska State Museum, and his wife, Jane, had collected fossils on the Colson farm in 1969. After the spring rains of 1971, Voorhies thought it would be worth another look.

"What drew us to the Colson Farm was a cliff nearly 100 feet high with a layer of very hard sandstone at the top," Voorhies remembers. "Like previous generations of fossil hunters, we had learned to expect bones in this particular sandstone. Jane and I found a few fragmentary fossils on our first visit—nothing exciting, but enough to prompt return trips. Our attention eventually shifted away from the high cliff to a series of less spectacular outcrops in Mr. Colson's pasture. It was here, on a deeply gullied hillside recently swept free of soil and debris by torrential rains, that a routine afternoon of prospecting turned into a once-in-a-lifetime adventure."

Searching a newly eroded gully, Voorhies found the fossil skull of a baby rhino protruding from the side of an ash bed.

"Excitedly, I brushed the ash away from the little skull," Voorhies continues, "first from the oversized teeth, then farther back, looking for evidence that the rest of the skeleton might be there."

Not only was the baby rhino intact, but Voorhies also found other intact fossilized skeletons in the ash layer that seemed to extend far back into the hill. Voorhies had made one of North America's great paleontological discoveries.

Cautious exploration revealed that the site was much too large to be worked by one person. In 1977, in order to obtain funding for large-scale excavation, Voorhies recruited members of the University of Nebraska State Museum to help document the site's extent and paleontological significance. When Voorhies proved that the deposit contained skeletons of both horses and rhinos (one of which contained a fossilized fetus), the National Geographic Society provided funding for a major excavation project.

During the summers of 1978 and 1979, excavation results exceeded even the highest expectations. Voorhies and his assistants unearthed 100 rhino skeletons, along with skeletons of three-toed horses, camels, birds, turtles and saber-toothed deer. Clearly, the site was a paleontological treasure, and the record of some type of major ecological disaster.

During the excavation work, Voorhies carefully noted the positions of the fossilized skeletons, photographing and sketching each one before encasing them in plaster casts for removal and later laboratory study. The arrangement of the skeletons in the ash bed followed a definite pattern. Digging down from the top, Voorhies found rhinos first, then, at deeper levels, smaller hoofed animals such as horses, camels and deer. The birds and turtles were always at the very bottom of the ash bed, along with numerous footprints of rhinos and other hoofed animals. The smallest creatures had obviously died first by direct burial in the ash, followed by the middle-sized animals, and finally by the rhinos.

Many of the horse and camel bones showed bite marks inflicted by large scavengers, which had reached the carcasses before burial. Furthermore, abnormal, porous, superficial bone growths on every large fossil animal—symptoms of lung failure in modern species—indicated that they died of lung failure caused by the inhalation of large amounts of volcanic ash. Citing this evidence, Voorhies believes that the larger animals died more slowly, over a period of a few days or weeks.

By the end of 1979, paleontologists decided to no longer collect fossils from the ash bed, but instead to expose them in place as a future public exhibit. In 1981, *National Geographic* magazine, along with newspapers and network television news programs, publicized the site. In 1986, the Nebraska Game and Parks

continued on next page

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Foundation took the first step toward opening the site to the public by buying the land.

When Voorhies discovered the site back in 1971, he named it the Poison Ivy Quarry. During the excavations of the late 1970s, it was known as the Ash Site. Today, it is Ashfall Fossil Beds State Historical Park, a joint project of the University of Nebraska State Museum and the Nebraska Game and Parks Commission. The park opened to the public in 1991.

The park Visitor Center features interpretive displays and a working fossil preparation laboratory. Educational programs are presented on a regular basis and visitors are invited to ask paleontologists about their work.

The nearby, 2,000-square-foot Rhino Barn covers a partially excavated portion of the fossil-bearing ash layer, and ranks among the most remarkable of all paleontological exhibits. Each summer, paleontologists continue to uncover fossils, leaving the newly exposed skeletons in place exactly as they are found. Specially constructed walkways afford visitors an unobstructed, close-up view of the fossil skeletons and paleontologists at work. When the area within the Rhino Barn has been fully excavated, the building will be extended to cover more of the fossiliferous ash layer and to protect ongoing excavation.

The three-dimensional preservation of fossilized skeletons and their often lifelike positions makes a remarkable exhibit with enormous paleontological importance. While fossil skeletons of individual animals are not that unusual, catastrophic events that preserve populations or communities of animals are quite rare in the fossil record. In their studies at Ashfall Fossil Beds, paleontologists have gleaned information on population dynamics, diet, disease processes and even certain aspects of social behavior.

Among the fossil rhinos, several mother/baby pairs have been found, along with young rhinos in actual nursing positions alongside adult females. Stomach and mouth areas of some skeletons even contain the fossilized remains of the last meals of grass seeds and leaves.

To date, paleontologists at Ashfall Fossil Beds have discovered skeletons of barrel-bodied rhinos, which weighed as much as two tons; crowned cranes; giant tortoises; five species of ancestral horses, which range in size from modern sheep to Shetland ponies; three kinds of camels; hornless, saber-toothed deer; and a number of small predators that resemble modern raccoons and foxes.

The sandstone strata just below the ash layer contains many partial remains of animals that lived and died during the several hundred years preceding the catastrophic fall of volcanic ash. Among them are four-tusked elephants that weighed as much as five tons; 150-pound, bone-crushing dogs; three-horned deer; 100-pound browsing horses; 150-pound, leaf-eating mammals called oreodonts; and horned rodents.

In future excavations, paleontologists hope to find skeletons of the large predators that roamed Nebraska's Pliocene grasslands—perhaps saber-toothed cats or bear dogs. Bite marks on bones already collected, together with fossilized droppings containing chewed bone pieces, reveal that big meat-eaters hunted at the ancient water hole.

The story of the discovery of Ashfall Fossil Beds should indicate to fossil collectors and amateur paleontologists the importance of reporting certain finds to professional paleontologists at museums and universities. Had a fossil collector found that baby rhino skull protruding from the ash bed, rather than a paleontologist, that skull, at best, might have ended up atop a mantle, gathering dust in a private display case, or being sold for a modest sum of money. The scientific value of that fossil skull—and its attached skeleton—would have been lost forever, and the world would have been deprived of a great paleontological exhibit.

Along with spectacular fossil displays, Ashfall Fossil Beds State Historical Park offers educational programs on a regular basis, and welcomes group and school tours with advance arrangements. Collecting fossils on the park grounds is strictly prohibited.

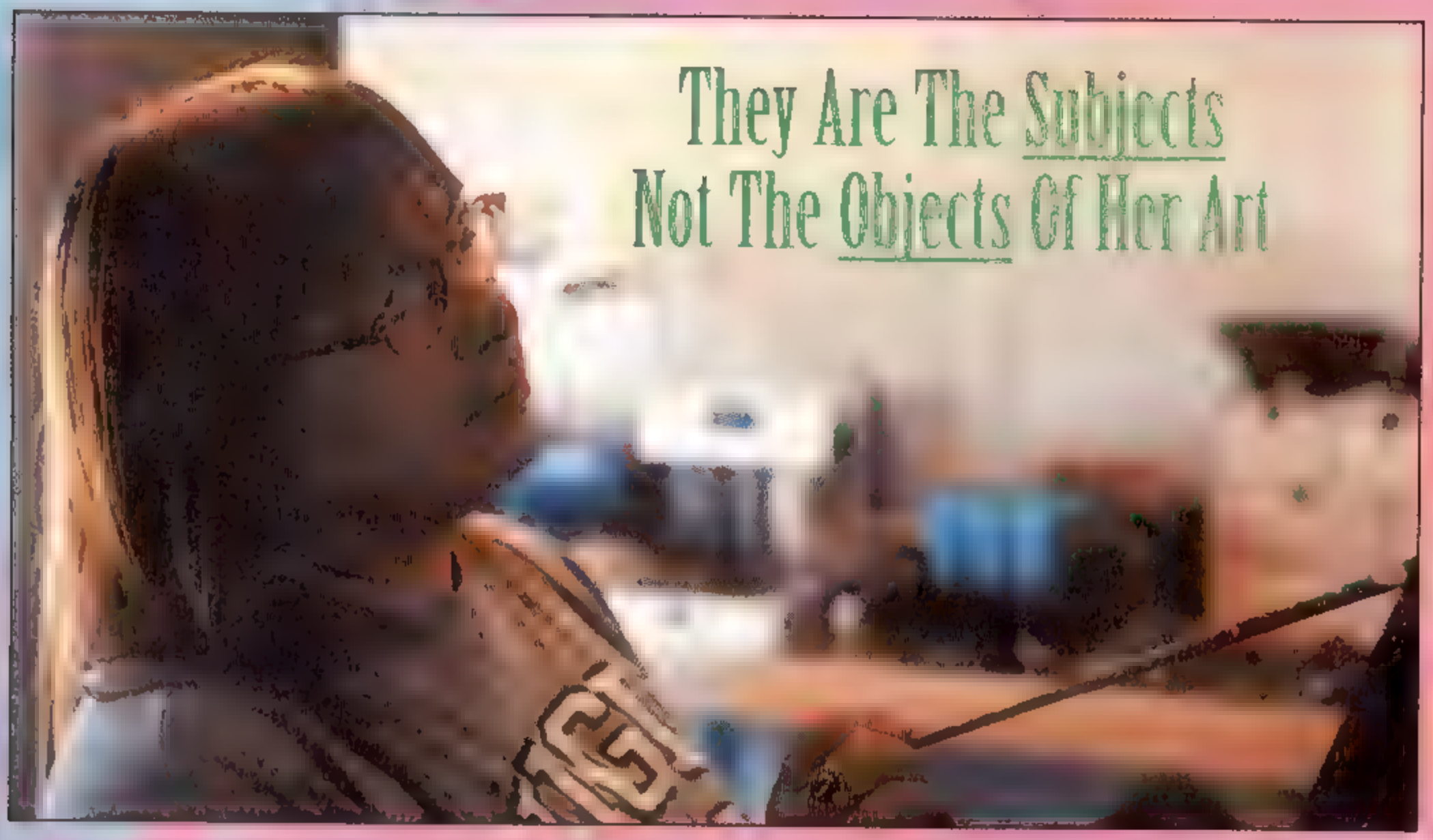
Ashfall Fossil Beds State Historical Park is open to the public from May 1 through mid-October. The peak of the visitor season is from Memorial Day through Labor Day, when the park is open from 9 a.m. to 5 p.m. Monday through Saturday, and from 11 a.m. to 5 p.m. Sunday. Before Memorial Day and after Labor Day, hours are 10 a.m. to 4 p.m. Tuesday through Saturday, and from 1 p.m. to 4 p.m. Sunday. For further information, call (402) 893-2000, or write to Ashfall Fossil Beds State Historical Park, P.O. Box 66, Royal, Nebraska 68773.

Ashfall Fossil Beds State Historical Park is located six miles north of U.S. Highway 20 and the towns of Orchard and Royal. Limited accommodations and facilities are available in Royal and Orchard. O'Neill, Nebraska, population 6,000, located 25 miles west of the park on U.S. 20-275, has more to offer in the way of restaurants and overnight accommodations.

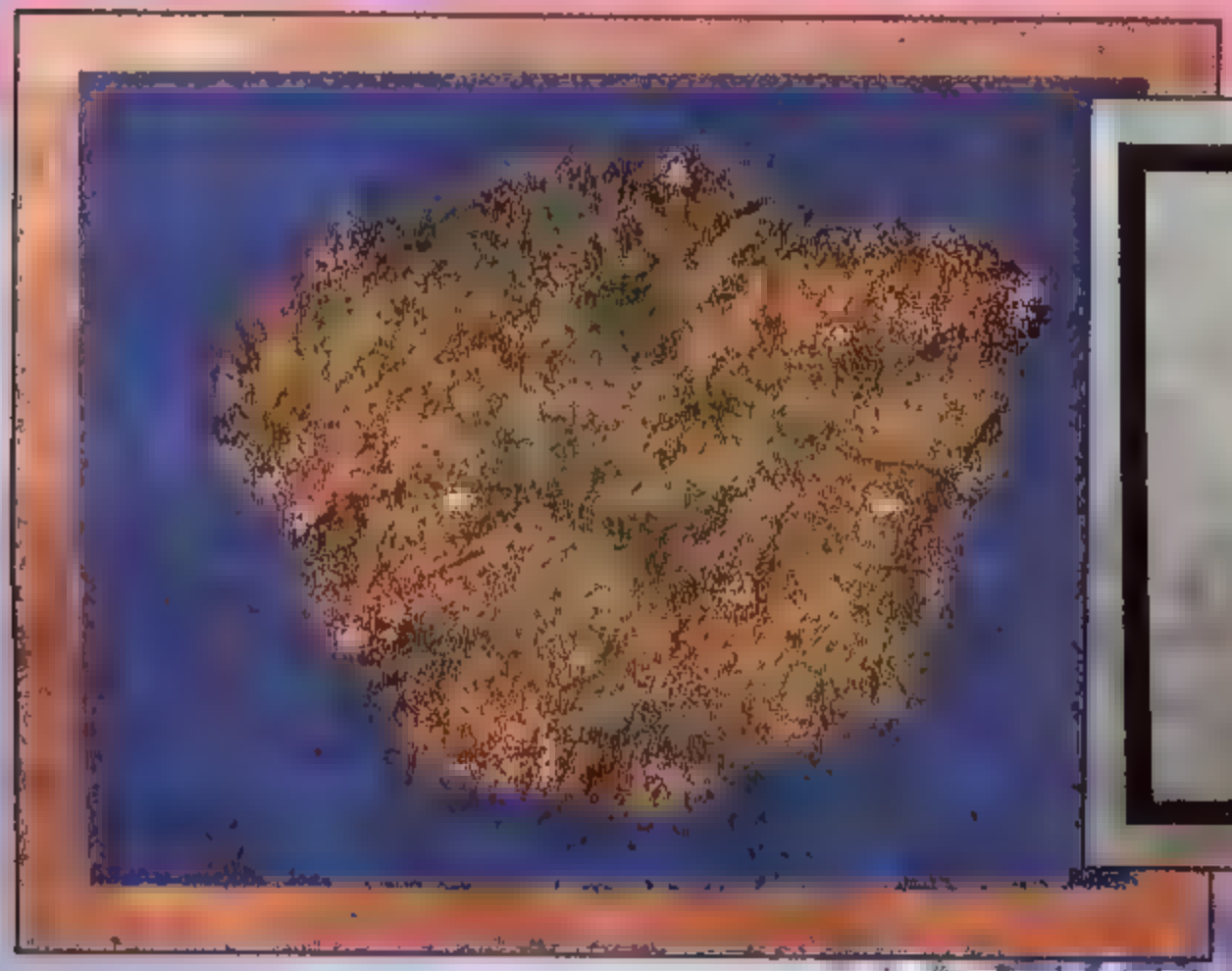
Although Ashfall Fossil Beds State Historical Park is a bit off the beaten path for most travelers, a visit is well worth the time and effort. You can see many excellent paleontological exhibits in museums—but nothing quite like Ashfall Fossil Beds.

She Paints

They Are The Subjects Not The Objects Of Her Art

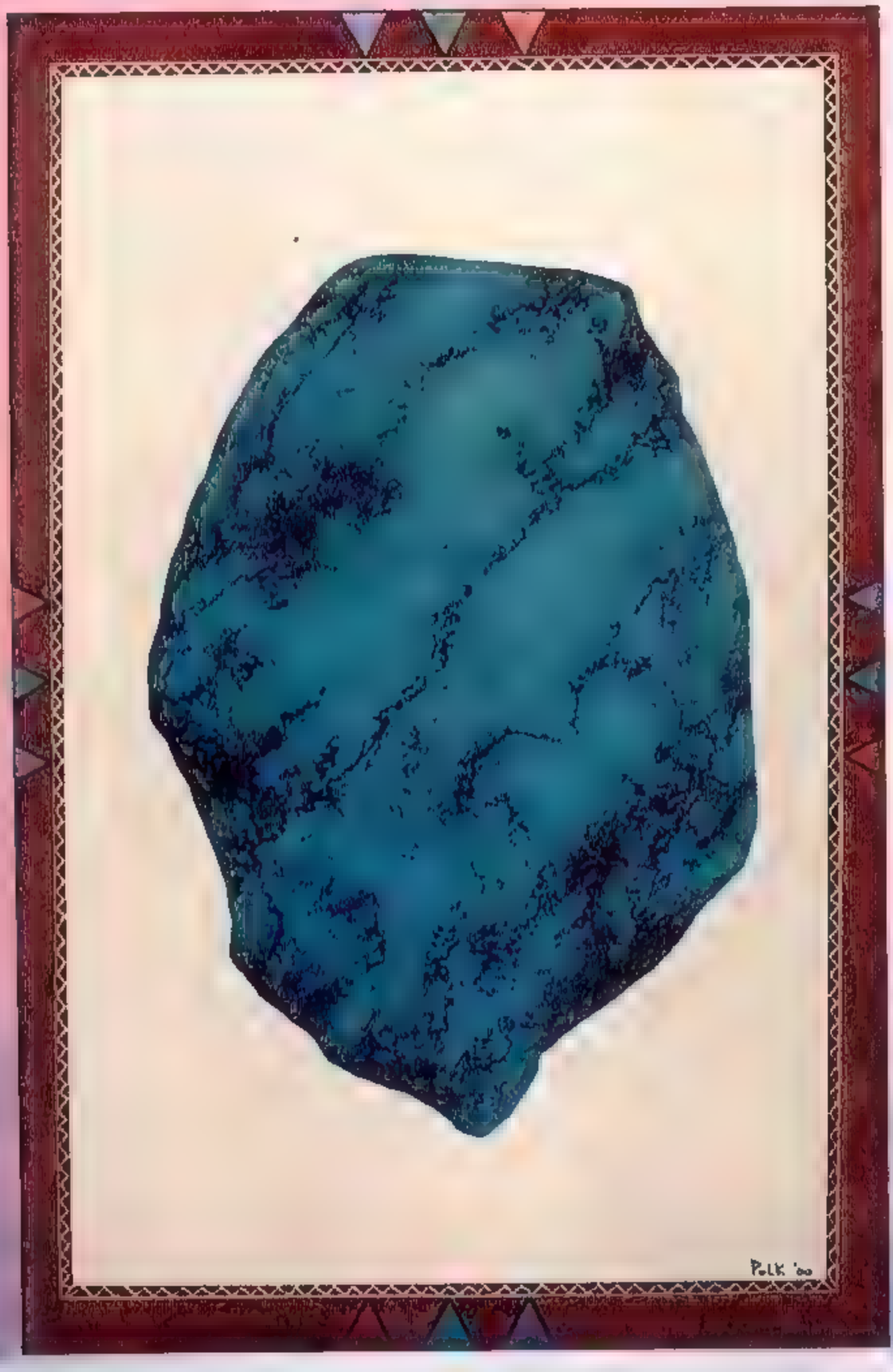


Artist Patti Polk (top) took inspiration from her hobby. A piece of poppy jasper posed for this portrait (below, left).



The patterns in rocks can resemble other things, like flowing water or canyon walls

Rocks



Turquoise isn't just for bolas anymore. It's used for a variety of Southwestern artwork.

This bold design is a representation of a piece of petrified wood

Editor's Note: A new phase of the rock collecting hobby is painting what you find. Patti Polk has been kind enough to give us some insights on how she paints images of her favorite rocks. Why not get started yourself?

by Patti Polk

My interest in rockhounding didn't really begin to flourish until I moved to Tucson in 1994. But I have always been an artist, and have painted and drawn pictures as far back as I can remember. Born and raised in Los Angeles, I developed my painting techniques without much in the way of formal art-school education—pretty much what I've learned, I learned on my own, through on-the-job training, books or personal experimentation with a large variety of media.

In recent years, before coming to Arizona, I made a living as a scenic artist, painting scenery, sets, backdrops and murals for movies, TV, theme parks (Disneyland, Universal Studios, Sea World), and big Las Vegas casinos (Treasure Island, MGM Grand, New York, New York). I have always had a love for the desert, and a desire to live in the beautiful, wide open spaces of Arizona, so on Jan. 1, 1994, with no job prospects, no friends, and a heaping dose of optimism, I decided it was time to go and I packed myself up and moved to Tucson.

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Paints Rocks/ *from page 29*

While in Tucson, I started my own business, painting murals and decorative paint finishes in people's homes. And, far more importantly, I joined the local rockhound club and was off and running with the newfound love of my life—rocks!

I didn't really remember until fairly recently that, when I was a child, my dad and I would go out roaming around the desert shooting at tin cans. On all those trips, I had always been busy picking up precious little stones and taking them home for evaluation and safekeeping. Pretty goofy, eh? Well, we all know how that goes!

Anyway, after a year, I felt a little crowded in Tucson, so I headed north to find a smaller town, and lo and behold, I found the perfect place—Cottonwood, Arizona! What more could a rockhound/artist ask for? Sedona is right next door, with some of the best galleries in the country, and so centrally located in the very middle of the state, that going in any direction I can be at any Arizona rockhound area within four hours. I am a rockhounding fool, and will always jump at the chance to get out there and find some rocks, sunshine and fresh air. My regular stamping grounds are all over Arizona and Southern California, with an occasional venture into Utah and New Mexico. My personal favorite collectibles are agates—especially anything that contains some kind of combination of purple, red, pink, yellow and blue. I love all the incredible variety of color and pattern that you can find in the agates—everything from just the simple, lovely fortification banding to the exquisitely elaborate feathers that you find in the best plume agates. I used to do quite a bit of cabbing, but now I usually just polish one side and keep them as ornamental specimens. I also enjoy lots of other types of rocks—crystals, minerals, fossils—or anything that's a good excuse to get out and do some rockhounding.

After moving to Cottonwood, I floundered for a little while trying to figure out what kind of painting I would like to do. I tried a few different subjects, but nothing really excited me enough to keep my interest beyond doing just one painting. Finally, I reached a point where I asked myself, "What do you enjoy doing more than anything else?" And, of course, the answer was "rocks." At first I thought it was a crazy idea, because I figured that no one would be interested in seeing paintings of rocks. Either they'd have the rocks themselves, or there just wouldn't be enough people interested in rocks generally to make it worth my while to paint them. I still have to make a living, so I have to be somewhat practical in my endeavors, but I decided to give it a shot, anyway. I chose some nice slabs that I felt had good color and pattern and that would hopefully be interesting to other people. As I first painted them, I felt woefully inadequate to capture the natural beauty of the rocks, because they are truly God's art—perfect in their own original form. As I progressed, I found myself captivated by the experience of having to study them so intricately in ways that I had never done before, ways that really made me feel at one with the rock itself. It truly gave me a whole new understanding of the nature of the rocks.

Generally, my technique consists of taking a piece of rough rock and slabbing it so as to expose the true colors and pattern that are so often hidden right inside. I've learned to look for that little telltale spot of color or marking on an otherwise dull-looking rock rind that conceals a beautiful prize just under the surface. I use all types of rocks as subjects—agate, onyx, petrified wood or whatever has the most pleasing color and pattern. I especially enjoy painting pieces that I've found myself out in the field, but I also use pieces that I've gotten from shows or as gifts from friends.

My paintings are usually done on canvas that is preprimed with gesso. Gesso is a mixture of plaster of Paris and white paint that is brushed all over the canvas first, as a ground for the succeeding layers of paint to adhere to. I pretty much use acrylic paints exclusively because they are water based, so cleanup is much less toxic than with oils, and I can work a lot faster with less drying time. All of the art supplies that I use can be purchased at any good art supply store.

Depending on the subject rock, there may or may not be a whole lot of planning time involved in the design. I first begin by picking my slab, positioning it on the table with a combination of natural and artificial light, and drawing a rough outline on canvas in pencil. I ponder the rock awhile to try to get a feel for the best way to paint it—should I go light over dark or dark over light, what colors do I need, or what layers go where, and so forth. I try to let the process be as loose and fluid as possible. Hopefully, I can capture the essence of the rock without too much interference from me.

Almost always, I complete the painting of the subject rock first, and then I paint the background around it using a color scheme and texture that complement the subject in an interesting way. While I am working on the painting of the rock itself, I build up layers of color, one on top of another, with semi-transparent washes, gradually transitioning into solid color. I keep working them back and forth until I get the depth, texture and qualities that finally look like the piece I'm working from.

I use all different sizes of acrylic paintbrushes, from 3 inches for covering bigger areas, to very fine for small, detailed lines. I use various types of feathers for creating veins and cracks, and sea sponges for special textures and effects. I mix my colors as I go, using plastic picnic plates as my working palette.

For the painting of rhodochrosite, I began by filling the rough outline with a random wash of light pinks, loosely following the lines of pattern in the rock. I went back over them with darker and darker versions of the same pink color, refining the shapes more and more each time I went over them. When I got them to a fairly good point, I then went in with an off white color and began the process all over again, this time refining the white spaces until they looked right, too. After that, I continued back and forth with both colors, using smaller and smaller brushes until I was working on the tiniest little swirls and dots.

During this process, I may do as many as 20 or 30 layers, depending on how complicated or intricate the patterns are. I use varying amounts of water to control the density of the paint and sometimes work the colors together wet. Sometimes I need to let them dry before adding the next layer of color.

When the rhodochrosite was done, I masked it off, using a combination of masking tape and liquid mask on the edges to protect it when I painted the background. I chose to paint the background completely black and then went over it with a silver metallic paint, applied with a wet sponge that I rubbed and dabbed all over, heavier toward the outside, and lighter as it came in, leaving a halo effect around the rhodochrosite.

To frame the rhodochrosite and to break up some of the background space, I painted a straight black line a few inches in from the outside edge, with a layer of black glitter mixed in for a little additional sparkle. When it was finished, I brushed on a couple of coats of a clear semi-gloss water varnish to seal it completely against any accidental damage.

When I paint various types of rocks, I generally use the same basic processes but in different sequences or with additional painting techniques. For instance, when I painted a picture of turquoise, I started by doing the same basic outline of the shape, but I used a mixture of three different shades and lightnesses of blue-green colors that I worked until I achieved the right balance of color that matched the specimen. Once I had that, I went in with a green-black color for the veining that I applied with a feather, using a twisting motion and sponging it with water. Again, I went over and over it with varying amounts of water until I

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Paints Rocks/ *from page 31*

got the exact blend I needed. I have found that color is everything! If your color isn't right, your painting will never look good.

After putting in the veining, I went back over it once again, this time with the turquoise colors, to soften everything down. I then masked it off and proceeded with the background. I decided that a neutral cream color would offset the turquoise nicely, and I just brushed that in all over the remaining area. When the cream color was on, I felt that it needed something more to finish it off, so I put in a border all around the outside edge.

For the border treatment, I masked off about 2 inches and based it out in a terra-cotta color. I went over it with a crackle finish and covered that with a brown color. When you use a crackle medium and put paint on top of it, it cracks and shows the paint color underneath. It has a really nice effect—sometimes it looks really old or like leather, depending on the colors you use. In this case, it looks like leather.

I was happy with the border so far, but it still needed more. I added some triangle designs and filled them in with metallic purple, aqua and bronze. I outlined them in black lines with a paint pen (a lifesaver when you need straight lines!), and used a gold pen to draw the little freehand zigzag designs all along the inside edge. At that point, it seemed finished, so I signed and varnished it.

One of the things I really like about these paintings is that they often look like other things besides what they are. A rhodochrosite painting can look like the sides of a canyon, a painting of turquoise can look like flowing water, or a painting of poppy jasper can look like a field of blooming flowers. I never intend for that to happen, it just does of its own accord.

Sometimes, I also do other kinds of paintings about rockhound trips that I've taken. The paintings are mixed-media collages of images that I remember about the trip, with actual portions of a map of the area glued in, painted sections of the hills and mountains, paintings of pieces that I collected there, and decorative elements such as textural surfaces using plaster, copper strips, glitter, glass, metal leaf and whatever else seems appropriate at the time. My work is constantly evolving, and even I don't necessarily know what I'll be doing next!

If you'd like to know more about Patti's work, you can contact her at polnel@verdenet.com or (520) 649-3744. If you'd like to see more of her work, visit her Web site at pattipolkrockart.8k.com.

The Fight for

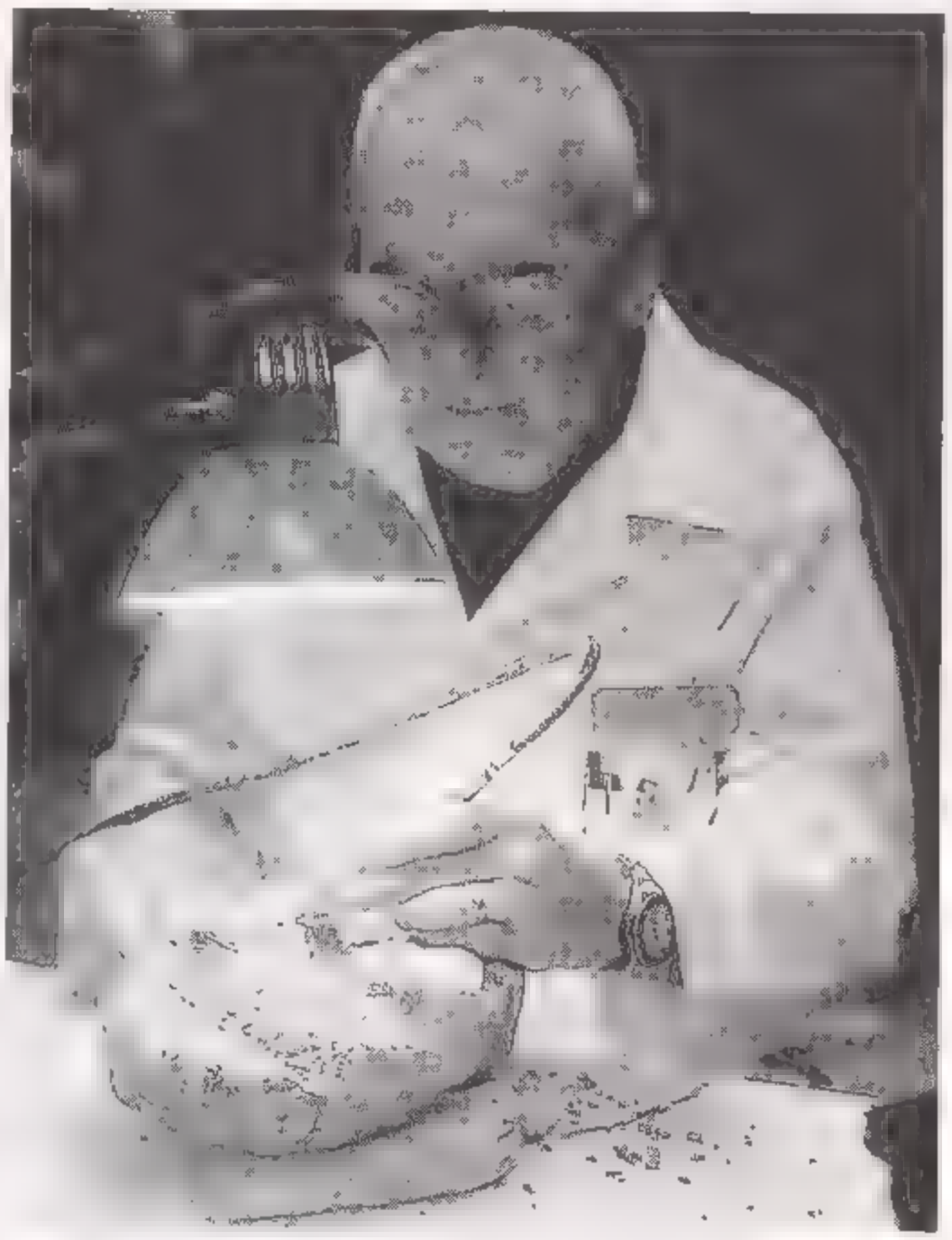
Will Paleontology Leave Fossil Collectors Behind?

by Steve Voynick

According to the old adage beauty is in the eye of the beholder. Well, when it comes to fossils, value seems to be in the eye of the beholder. Collectors value fossils as curios, display pieces and even as objects of art. Amateur paleontologists value fossils as indicators of the basic physical characteristics of ancient life forms. And commercial dealers value fossils as merchandise that can be marketed for profit.

But fossils are of greatest value to today's paleontologists. Thanks to high-tech science, fossils are now yielding information about ancient life that is unprecedented in both quantity and quality. The fact that fossils have greater scientific value than ever means three things. First, our understanding of the ancient world will increase rapidly. Second, the debate between professional paleontologists and amateurs as to who should get their hands on fossils will intensify. Finally, the rapid advancement of high-tech paleontology, coupled with the static nature of fossil collecting, promises to further widen the growing gap between professional and amateur interests.

As late as the 1960s, paleontologists and fossil collectors had been in common. Both groups obtained fossils by the traditional method of visually searching out



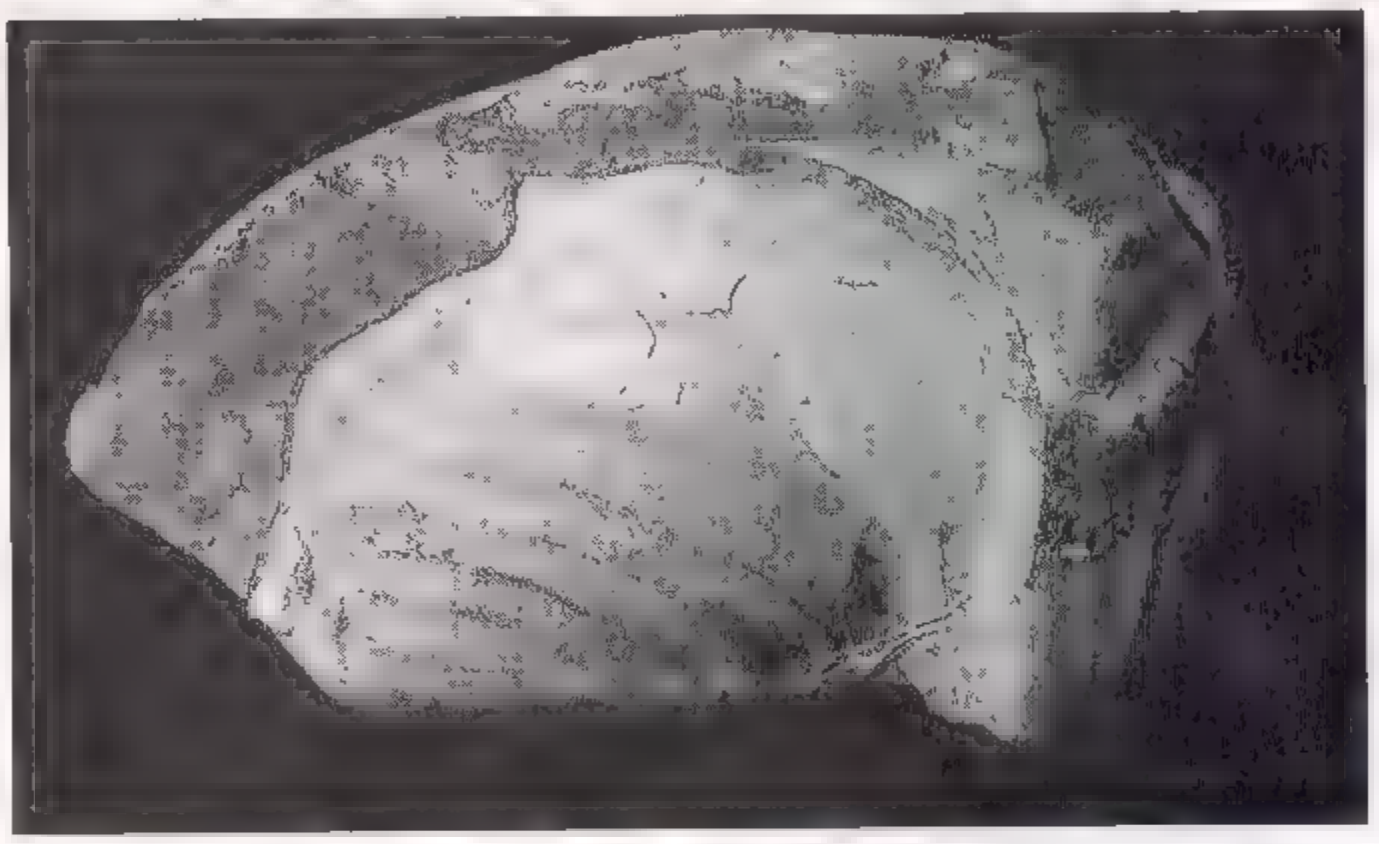
When scientific advancements help paleontologists learn so much from fossils nowadays, is it right for amateur collectors to keep their finds?

crops and eroded areas of fossiliferous formations. And to both paleontologists and fossil collectors, fossils were primarily indicators of the general physical nature of ancient life forms.

Back then, paleontologists spent much of their time excavating, classifying and preserving fossil bones, reconstructing the skeletons of vertebrates, and making usually conservative observations and interpretations about the origin of animals. Their research and interpretation were straightforward and easily understandable to amateur fossil collectors.

But those days are gone forever. Paleontology currently makes use of more high-tech subsciences than most other scientific disciplines. Amateurs now have difficulty even keeping informed of the steady stream of advancements in paleontology. In just the last couple of years, paleontologists have recovered the fossilized remains of the biggest known predator, *Giganotosaurus carolinii*, an eight-ton giant even more ferocious than the fabled *Tyrannosaurus rex*, and they have discovered fossils of the smallest known mammal, a tiny tree dweller that weighed less than an ounce. Paleontologists are redefining the divisions of geologic time, pinpointing the times and durations of the great extinctions, and recovering protein fragments and DNA sequences from fossils tens of millions of years old. The bottom line is that today's paleontologists are painting pictures of ancient life and paleoenvironments with detail and accuracy that their predecessors could only dream of.

Fossils



Fossils like this Inoceramus *gave support to the breakthrough theory of warm-blooded dinosaurs.*

A Better Handle On Time

By definition, paleontology is the study of ancient life as reflected by the fossil record. But it also is a study of time, for accurate geologic time frames are essential to putting evolutionary events into meaningful perspective. Even as late as the early 20th century, our concepts of geologic time were rudimentary. But, today, geochronology, the subscience of dating rocks and fossils, has dramatically restructured and refined our framework of geologic time, and thus of paleontology itself.

The ability to accurately determine the age of rocks had eluded scientists for centuries. Due largely to rigid concepts of creation, the idea that life could be older than several thousand years had always seemed improbable. But, in the 1700s, early geologists realized that sedimentary rocks are laid down horizontally, with younger strata deposited atop older strata. To date specific strata, geologists noted their positions in local stratigraphic sequences, then measured those positions against known current rates of geologic deposition. When calculations indicated some strata were actually several million years old, many scientists thought the idea was preposterous.

But, by 1915, physicists had determined the decay rates of various isotopes in the uranium decay chain—the first step toward modern radiometric dating. By measuring the relative proportions of uranium and stable lead in samples, physicists were finally able to measure the age of igneous rock. Their findings pushed back the scale of geologic time by billions of years, and revealed that many common fossils were actually hundreds of millions of years old.

Radiometric dating made possible the subscience of geochronology (literally "earth dating"). But the early, crude analytical methods of quantifying trace amounts of uranium and lead created dating errors of 30 percent or more. In 250-million-year-old Permian materials, that translated to chronological errors of 25 million years. Although that accuracy could establish general geologic time frames, it could not pinpoint dates and durations of specific events.

By the 1960s, geochronologists had developed a radiometric dating method that compared argon and potassium isotope levels with a margin of error of 5 percent. Then, in the 1980s, the new argon-argon method compared two argon isotopes, one synthetic and one natural, with a margin of error of just 2 percent, or roughly 5 million years in Permian Age materials.

Geochronologists are now applying their high-tech dating methods to the devastating Permian extinction, which eliminated three quarters of all existing species, and even once thought to have lasted 10 million years. Examining samples of volcanic ash layers from a site in China marking the Permian extinction layers, geochronologists noted microscopic crystals of zircon. When formed, zircon incorporates trace amounts of uranium into its crystal lattice. The uranium-lead ratios that exist today indicate the age of the crystals, and thus of the ash layers. Using state-of-the-art analytical equipment, geochronologists have now determined that the Permian extinction occurred between 252.3 and 251.4 million years ago, a much shorter duration than previously thought. With an error of just 0.1 percent, the dating is accurate to within 250,000 years.

Dr. Paul Renne, a geochronologist from the University of California at Berkeley, calls the results "a tour de force of geochronology." According to Dr. Renne, some geochronologists believe that within 10 years dating error may be reduced to 0.0004 percent—or a Permian-time error of just 10,000 years. Such accuracy in dating will give paleontologists a much sharper picture of evolutionary processes.

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High-Tech Paleontology

High-tech science has transformed virtually all areas of paleontology. CAT scan instruments now routinely analyze internal fossil features, including dinosaur skulls. Chemists recover protein from dinosaur bones and break it down into component amino acid "strands." Comparison of fossil DNA strands with those of living birds and crocodiles has revealed a much closer relation between Cretaceous birds and reptiles than was previously thought. Meanwhile, isotopic analysis of fossils materially supports the theory of warm-blooded dinosaurs.

Not everyone realizes that computers play a major role in modern paleontology. To handle the flood of new data being produced by high tech analysis of fossil materials, paleontologists rely on high-speed information storage and manipulation systems. The sheer volume of computerized data now available, and the ability to process it rapidly, has altered the entire paleontological thought process.

To establish relationships among species that were published in the 1960s or before, paleontologists once had to rely entirely on the original writers' authority and assertions. Errors and misconceptions survived for decades, delaying the overall scientific process.

"But now we lay our data out, then construct and analyze it within a hypothetico-deductive framework," says Dr. Richard Stucky, a paleontologist with the Denver Museum of Natural History. "We do the science differently today by using hypotheses, massive data sets, and higher powered analytical techniques that include statistics and cladistics."

Cladistics refers to biological systematics based on phylogenetic relationships. Phylogeny addresses evolution by considering continuous development of genetically related groups of organisms, as opposed to that of individual organisms. Cladistics requires the analysis of huge amounts of data, and imparts a much broader perspective to paleontology.

As examples of that broader perspective, paleontologists now study not only evolution, but ecological factors that affect evolutionary processes. They have recently gained great insight into paleoecology, the study of ancient environments. This has produced concepts like that of phylogenetic equilibria, the idea that species evolve continuously, but at varying rates, and that their evolution tracks the changes in their physical and biological environments. Another is that of punctuated equilibria, the idea that species remain relatively stable for long periods of time, then evolve in spurts associated with environmental change. While both patterns are well supported by the fossil record, paleontologists are not yet sure why each occurs.

The sheer volume of accurate, new data has given paleontologists a growing confidence in their ability to interpret and extrapolate that information into bold, creative and valid ideas about the ancient world. Just 25 years have passed since paleontologists broke a century of traditional thought with brazen ideas of warm blooded dinosaurs. Since then, paleontologists have proposed many other nontraditional, yet scientifically supported, ideas.

One of these ideas evokes images of the movie "Jurassic Park," in which fictional paleontologists re-create dinosaurs by cloning DNA samples taken from amber fossils of insects that preyed on dinosaurs. Paleontologists readily admit that it is improbable that we will ever clone dinosaurs. But DNA, or deoxyribonucleic acid, is the recognized basis of heredity in most life forms, and its recovery from fossils opens exciting new frontiers in paleontologic research. Paleontologists have already learned that DNA fragments can survive in dinosaur-age fossil material, and that those fragments can be chemically amplified into representative genes. Direct molecular comparisons of "fossil" genes with those of modern species will soon give paleontologists a much greater understanding of the fundamental mechanics of evolution.

More Fossils

Because of the remarkable analytical capabilities of high speed computers, today's paleontologists need to process even greater amounts of data — and that means they need more fossils to study. Accordingly, more paleontologic field location and excavation work is in progress around the world today than at any time in history. The job of finding fossils is much more efficient, thanks to Earth-orbiting satellites that generate high-resolution, electronically enhanced, photo-computer images. The images, actually radiographic records of reflections of invisible infrared, thermal and microwave radiation, are invaluable in identifying surface geological features.

Individual types of soil and rock have specific spectral reflectance values. By comparing satellite-generated radiographic data with known energy reflection absorption characteristics, paleontologists are now able to identify outcrops of fossil-rich formations on radiographic maps, thus greatly increasing the odds for success in ground fossil surveys.

Global positioning system (GPS) and computerized global information system (GIS) technologies have become standard in paleontologic field location and mapping work. GPS and GIS are largely responsible for the many new vertebrate fossil discoveries made recently in remote, poorly mapped regions of China.

The stepped up professional search for fossils focuses attention on the questions of accessibility to, and protection of, fossil resources. Many paleontologists favor restrictions on nonscientific fossil collecting, arguing that many paleontologically priceless fossils are being lost to amateur and commercial collectors who are unable to study them properly.

Conversely, amateur and commercial collectors claim the right to collect fossils just as they collect minerals. They argue that not nearly enough paleontologists exist to collect and study all the fossils that are exposed by weathering and erosion each year, and uncollected fossils inevitably weather away to nothing. Therefore, amateurs claim, it is pointless to limit fossil collecting only to the scientific community.

The U.S. Bureau of Land Management has already imposed fossil-collecting restrictions on millions of acres of fossil-rich Western public lands. Amateur and commercial collectors are banned from collecting vertebrate fossils as well as from disturbing specially designated occurrences of invertebrate fossils. Both vertebrate and designated invertebrate fossils may be collected only through authorized excavation, which means by accredited scientists.

On private lands, the debate is moot, for there the landowners call the shots. Still, ethics remain an issue. Should landowners find an usual fossil deposit on their land, a deposit that is both commercially and scientifically valuable, they must decide whether to accept monetary offers from commercial collectors or to turn the fossils over to paleontologists and take their reward in knowing that the fossils will benefit science.

Which direction the debate over fossil protection will take remains uncertain. But the wealth of information now provided by high-tech fossil analysis may very well swing the argument in favor of paleontologists. If so, amateurs should be prepared for even further restrictions on public-land fossil collecting.

Paleontology: The Profession

The well-publicized rush of advancements and discoveries in paleontology belies a surprisingly small professional field. To get an idea of employment figures, I spoke with Dr. Jere Lipps, professor and curator of the University of California's Museum of Paleontology at Berkeley. Dr. Lipps estimates the number of active paleontologists worldwide at no more than 15,000, with the greatest number in China and Russia. Only about 1,200 paleontologists work in the United States.

Dr. Lipps also offered some thoughts on what it takes to become a paleontologist today. Anyone considering a career in pa-

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leontology must have a deep interest in general science, plus a lot of determination Academically, an aspiring paleontologist should have a strong and unusually varied background in science, with heavy emphasis on geology and biology. Undergraduate training should include chemistry, physics, calculus-level mathematics, statistical analysis and computer use, along with specific courses in mineralogy, stratigraphy, sedimentary petrology, invertebrate paleontology, ecology, invertebrate and vertebrate zoology, evolutionary biology and genetics

All this leads to only a bachelor of science degree in biology or geology, the academic starting point for a career in paleontology A master's degree is the minimal requirement for employment as a professional paleontologist A position as a professor, researcher or curator demands doctoral credentials

In the United States, universities employ about 650 paleontologists, two-thirds of them in faculty positions Along with teaching, their university responsibilities include laboratory research and the supervision of field surveys and excavations.

Another 200 paleontologists work with private and government museums, with the National Park Service or with other government agencies, such as the Bureau of Land Management They are active in basic research; fossil excavation, preparation and display, geological surveys and mapping; evaluation of paleontological resources, and environmental-impact assessment

Most of the 350 paleontologists employed by industry hold master's degrees They work mainly for oil companies in the field of petroleum exploration, studying fossils to precisely identify, correlate and date petroleum-bearing and associated strata.

The New Paleontology

High-tech paleontology has already impacted the nature of museum displays at major museums like the American Museum of Natural History in New York City and the Denver Museum of Natural History The Denver museum's Prehistoric Journey exhibit, which opened in 1994 following a six-year, $7 7-million construction effort is internationally recognized as a showcase of modern paleontology.

"We departed from traditional exhibits that simply depicted ancient life" explains Dr. Stucky. "We focused instead on key events life's origin, the appearance of the first complex life forms, the first life on land, the origin of modern ecological habitats, and so forth and made them the teaching points We showed how the different sciences from physics, imaging and engineering to botany, ecology and taxonomy now contribute to our understanding of the history of life, and how the underlying science was performed"

Looking toward the future three primary assets will carry paleontology into the next century advanced analytical techniques that will coax more information out of fossils than ever before, faster computer systems to store, manipulate, analyze and transfer the obtained data, and a growing confidence among paleontologists to interpret and extrapolate that data into new ideas about the nature of the ancient world

In paleontology's immediate future, the nation's top scientists see an even greater reliance on high technology and cutting-edge science Dr Douglas Erwin a paleobiologist with the National Museum of Natural History (Smithsonian Institution) predicts that advanced, high resolution, geochronologic data will revolutionize the study of evolutionary rates, and that geochemical data will further integrate itself into paleontological studies to provide more detailed pictures of paleoenvironmental change

Paleontologists also anticipate development of more efficient methods to recover fossil DNA fragments University of California plant geneticist Michael Clegg says, "If we can [recover DNA] often enough, then it will become a real tool for evolutionary biological research. It could even lead to a whole new field, molecular paleontology"

As late as the 1960s, amateur paleontologists made significant contributions to the science But, today, professional paleontology has left them far behind Whatever direction paleontology takes in the future, it will do it hand in hand with high-tech science and state-of-the-art analytical methods, and without the need for amateur contributions

What does that mean for fossil collectors? The immediate answer is a widening gap between the interests of professional paleontologists and fossil collectors. As fossils become ever more valuable to science, it is only reasonable to expect further restrictions on nonscientific fossil collecting The debate on that point will continue well into the next century, but the balance is swinging in favor of the scientists

But further restriction on amateur fossil collecting would hardly be a total loss. On the positive side, every amateur paleontologist and fossil collector will be able to enjoy exciting new books and museum displays that answer in remarkable detail the questions we have long asked about such phenomena as the great extinctions and recoveries, the behavior of dinosaurs, the origin of life, and the evolution of mammals, including humans And that just might be a fair trade-off

Trilobite:
THE INDEX FOSSIL

Fossil hunters split shale layers at Antelope Springs, Utah, in the hopes of revealing trilobite fossils

It Holds A Special Place In Science

Nature's placeholder. The trilobite's presence helps scientists date rock layers.

by Bob Jones

When scientists began realizing the earth's history could be determined in part by studying rock formations, they immediately ran into the problem of trying to match up the ages of similar rock formations that were miles and even continents apart. Sometimes, their calculations showed certain rock formations were so similar as to have been formed at the same time, but they could not be certain. Today, we can use radioactive methods and other exotic tests to match things up, but in the old days it was done mainly by guesswork.

Enter our creepy little friend, the trilobite. Through careful study and extensive gathering of information, scientists finally realized that certain fossils lived at a particular time in the earth's history. If matching fossils were found in rock layers far apart, scientists could assume the ages of those two formations also matched. Then it was just a matter of dating one of those rock formations to determine the age of any formation with the same fossils. Since fossils form only in sedimentary rocks, this technique is only useful in dating these wind- and water-deposited rocks. Fossils that can be used to date rock formations are called index fossils, since they help index the age of certain rock layers. There are a number of index fossils now used, including our little ocean-going friend, the trilobite.

Trilobites were one of the first forms of life on earth to develop hard parts. These are critical to the formation of a fossil, since a creature with only soft parts, a worm, for example, almost never fossilizes. We only find evidence of a worm's existence through its burrows or tracks. Trilobites, on the other hand, developed a hard exoskeleton, which lent itself to mineralization, and so could be preserved.

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Trilobite/ *from page 41*

Trilobites are members of the arthropod group, represented today by such things as insects, lobsters, crabs, spiders and the like. They all have one thing in common: jointed legs. In the case of the trilobite, the legs were actually swimmers, which propelled this creature along the ocean floor in search of food. The tri- in trilobite refers to its three body parts: the head, called the cephalon, the thorax, where the internal organs were located, and the tail, called the pygidium. The hard casing that protected the little guy is called the carapace, a term we now use for turtle and tortoise shells.

When you look at a trilobite, you immediately see three longitudinal sections that run the length of the body. It's tempting to think these are the source of the "tri-" designation. That's incorrect. These sections result from two grooves that run the length of the animal.

The central part of the back between those grooves is called the axial lobe. It almost always shows horizontal thoracic grooves. Such grooves are important in identifying the various members of the trilobite family.

On either side of the axial lobe are the pleural lobes. Together, these make the trilobite immediately recognizable, even to the amateur.

Trilobites developed first in that vast period of time called the Precambrian. We have virtually no evidence of their existence then since they had yet to develop a carapace. Beginning with the Cambrian about 500 to 600 million years ago, evidence of trilobites is abundant, as the hard, protective shell had become a regular part of its structure. Given the number of trilobite fossils and their complexity, two things are apparent. There were a huge number of trilobites at that time, and since they were already well advanced, they had to have existed for millions of years prior to the Cambrian. Trilobites then became extinct over 200 million years ago.

Trilobites were highly developed by the time they could boast hard parts. Their very complex eyes also are evidence of their advanced development. The large bulging eyes of the trilobite are easily seen on the side of the cephalon. They were compound, which suggests a fairly well developed optical center in the brain to process the images received. Of course, as time passed, trilobites became more and more highly developed and specialized, something that is true of virtually all earthly creatures, though you might wonder about humans!

Trilobites tend to be rather small by animal standards. Most are something in the range of 2 to 3 inches, and even smaller in some cases. As time and evolution progressed, some trilobites reached quite enormous sizes, upwards of 2 to 3 feet. Some of these monsters have been unearthed in Canada. And don't be fooled by the smallish fossils you sometimes find. Trilobites often tended to curl up something like a hedgehog, probably as a means of protecting themselves. This is particularly true of the phacops trilobite. In many cases, the creature would die in that condition, and the fossil looks more like a small sword than the shape we recognize.

The trilobite you probably see most often is the cryptolithus, which is found abundantly in the Midwest and West. Antelope Springs, Utah, for example, boasts a shaley formation that's rife with cryptolithus remains. Collecting there is simple - just a matter of splitting the shale pieces to reveal both a positive and negative fossil image.

In the Midwest, where trilobites form in limestone rock, it is easy to obtain fine remains, which can then be used for lapidary work. Necklaces of trilobites are commonly made.

Another noticeable feature of the trilobite is the pointed spines that project from the pleural lobes. These are just extensions of those lobes, and undoubtedly gave the little guys added protection. Some of these spines grew to extremes, so they project a foot or more from the head, or cephalon.

As you collect trilobites, you have to be impressed with the vast number of these striated creature fossils we see. Trilobites were abundant, as I've said, but not that abundant. It seems these little guys were handicapped, just like crabs, their shells, once hardened, wouldn't expand as the softer parts continued to grow. So, like lobsters and crabs, there was only one thing to do, date the shell and grow a new one. The discarded shells would fossilize easily as they became covered with sediment. Today, we try to capture crabs when they molt, their hard shells and enjoy them as softshell crabs. I have to wonder if the trilobite's enemies also enjoyed softshell trilobite! We'll never know, since such doings are lost in the mists of time.

In the hobby of collecting fossils, trilobites, since they are so common and hardly spectacular, don't seem to get the attention or notice that the fancier fossils get. I can't imagine a film on trilobites that would compete with something like Disney's "Dinosaurs." Yet, where science is concerned, the lowly trilobite ranks well up among the more exotic fossil evidences, for it plays a significant role in the age dating and matching up of rock formations that may be on opposite sides of the globe. Remember that when you seen one of these heavily striated little guys.

Clinker Shale Fossils

Treasures From Burned-Out Coal Beds

by Sam and Ruth Kirkby

My husband, Sam, and I like to travel in the early morning and then stop for breakfast to break the monotony of long drives. On this particular trip, we were headed south in Montana when we saw a small restaurant that looked nice, with several truck trucks parked in front. The sign said Home Cooking, so we decided to stop and eat.

The tables were filled, but there were two spaces between men who looked like ranchers at the counter stools. They were friendly and struck up a conversation with us about where we were going. When we told them that we were seeking locations for fossil plants, the man sitting next to me asked which direction we were headed. I told him that we were planning to stay on this road to Wyoming. He was delighted.

Taking a napkin from the holder, he began to sketch a map to one of his ranches. He explained that, while he was clearing a place to locate a cattle tank, he had found "the prettiest leaf fossils" he had ever seen, and that they were on a pink shale. He told us to be sure and stop and take as many as we wanted, because he would be shoving the shales into a ravine when he went back to work on the ranch again.

We thanked him for the invitation and hurriedly ate our breakfast. I sketched the map and watched for the landmarks that he had described while Sam did the driving. In about 30 miles we came to the wire fence and a big, wide gate. I jumped out and opened the gate for Sam to drive through, then closed it to prevent any cattle from getting out, as the rancher had asked us to do.

The little dirt road ran along a ridge for about a mile, and then we saw the area the rancher had described. He had scraped the top of the ground to make way for the cattle tank, and had piled up the pink shales on each side.

We climbed out of the pickup and looked at the freshly dug shale heap, and it seemed like each slab had a fossil. This was wonderful, because we usually had to dig and search for our specimens, and here they were, all ready for us to collect.

I found the leaves, several nuts and a beautiful catkin of Corylus insignis, counterpart of the modern filbert tree. Dr. Roland Brown, in reporting on the Paleocene floras of the Rocky Mountains and Great Plains in 1962, was only able to find one nut. As it was small, he assumed that "shrinkage had occurred." Since so many of these deposits have been found in burned out coal beds, it is possible that the specimen was diminished in size from the heat.

Sam was finding an abundance of leaves of cattail and some very small gastropods, indicating a swampy environment, at his site. We both enjoyed the abundance of specimens, and found it difficult to select the ones we would save.

We had a stack of beautiful specimens all piled up, and as we moved the shales together they made a musical ring. It was getting late, and Sam suggested that we sort our specimens. I kept exclaiming about how different and smooth the rocks were from so many other shale sites. Sam told me a story that he thought might explain how these shales were formed.

"In 1931, I and two of my friends, Russell Hower and Jim Mapes, formed a small band called the Michigan Stump Dodgers. As people do in small towns, everyone went to town on Saturday night. I was late getting started because I had a flat tire, and the only parking place was in front of the Ford agency. There in the window was a beautiful olive green Model A Ford with apple green wheels. I could not resist the offer that the salesman made, and ended up buying a brand new car.

"To celebrate my new car, Russell, Jim and I decided to make a trip out West and to sponsor our trip by playing for dances.

"We drove west to Douglas, Wyoming, where we booked our first dance. The people were happy, and suggested that we get a hall and play every weekend, but there was not another building or house in sight, and we had some doubts about getting an attendance. The hall was 60 miles north of Douglas at a place called Dry Creek, and the emptiness seemed so vast.

"The first night, we could not believe the number of people who would drive miles to go to a dance. We were delighted to meet such nice, friendly people, and they took us in like old friends. During the week, we helped them with their harvest and we went horseback riding with their daughters. They even invited us to sleep on their kitchen floors. Sometimes we went antelope hunting during the day, and then they invited us to help with the cooking, which I liked.

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Burning often turns fossiliferous shales a vibrant pink. A fossil leaf of* Annularis stellata *(left) was collected in North Texas. This* Corylus insignis *(above) was found in Montana.

Clinker Shale/ *from page 45*

They told us about the local points of interest and they kept mentioning the burning coal mines. One afternoon, we decided to drive out and see them for ourselves.

"We had the directions, and started to drive out east of the main road. We traveled in a pair of ruts the whole trip. There was only flat land and nothing on the horizon. Just when it seemed we were going to be traveling forever in those ruts, we suddenly saw a speck on the horizon. As we came closer, it appeared to be a dirty shack, with a girl about 18 years old and two dogs sitting in front.

"I asked her if we were headed in the right direction to see the burning coal beds. She said, 'Yes, but you should stay until dark, and then it will really be spectacular.'

"It was already late in the afternoon and so we continued on for many more miles until we saw some haze from heat on the horizon. We decided to stop and walk for a while to be sure we were headed in the right direction. There were no signs, no fences, and we didn't want to fall into a sudden hole in the earth.

"In about 100 feet, we came to a blast of heat and a crack in the ground through which we could see fire. Flames were licking at the edges, and it was surprisingly hot. We knew that we had to be careful, or we might drop out of sight forever.

"We decided to go back to the car and toss our bedrolls on the ground and take a nap. When we awoke, it was dark and the beds looked like the lights of a great city with flames here and there. We walked with great care, as we didn't want to fall into this cauldron of fire. One crack was about 18 inches wide, but it ran for about a half mile, with flames licking at the surface all the way.

"When we decided to leave, we began to worry about getting lost in this vast country with just the ruts to guide the way. We watched every minute to be sure that we stayed the course to the main road. It was one night we would long remember."

When Sam finished his story, I realized that he was suggesting that these shales had been part of a burning coal bed. Of course, I wanted to learn more about these events and the transformation of rocks. This became an entrancing idea as I studied the formation of the layers of the earth.

How did these beds of coal catch fire? There are numerous theories, and the one most often suggested is that the fire was started by lightning. Spontaneous combustion is considered to be the most likely as coal is combustible. When a stream cuts through a bed of coal and creates a ravine, exposing the coal seam to the atmosphere where there is a good supply of oxygen, the coal will catch fire more readily.

A fast cutting stream may break the coal into pieces small enough that the sunlight can generate enough heat to ignite a fire. Western coal is generally of the lignite or subbituminous kind and will ignite at much lower temperatures than the harder coals. When combustion starts at the surface and spreads, it may allow cavities to form where gases can accumulate, and in time the crust may collapse and allow more oxygen to enter and fuel the fire.

The baked material produces a musical tinkle when struck, earning it the nickname "clinker shale."

The greater part of the original sediments is a mix of shale and sandstone. When they are subjected to the heat from a burning coal bed, they will generally turn pink or red in color. The pink is caused by minute scales of hematite and the degree of metamorphism. Some beds are formed of mottled colors, which are thought to be caused by a very high temperature.

I saw one stratum in Utah where the bed had burned for about 200 feet, but the rest of the coal bed was unaffected, possibly for the lack of oxygen. Erosion had stripped away the covering of the strata, and the sight was dramatic.

Rocks within a few feet of the top of a coal bed may be fused, while those beyond may be baked, and those further on may be only slightly reddened. It is interesting to note that some of the sediments may retain their original texture, while others will only be slightly affected.

Both physical and chemical factors are responsible for spontaneous combustion. The coal that is highest in volatile matter, moisture and sulphur is generally the most likely to ignite, or an outcrop of lignite that is exposed to the hot rays of the sun will ignite more readily than unexposed coal. I thought it interesting to learn that some of the burned-out layers were left as magnetic.

I am particularly interested in rocks from the Paleocene Epoch, and have observed from a distance the buttes in Montana and North Dakota, whose sands of red coloration show where coal beds have at one time been burned. Close examination of these deposits will usually reveal you to find some fossil plants.

Many other locations have burned-out coal beds. In my explorations I have discovered burned shales in California, Oklahoma, Pennsylvania, Utah, Wyoming, Texas and Nova Scotia. Look at the shales that are metamorphosed around a coal mine to discover some unusual fossils.

I was once told that a deposit in Texas was only black shale of the Carboniferous Period. I was also told that it was called the Red Dog Formation, which I have not been able to confirm. However, I discovered a small section of shale that had been burned, and the preservation of the plant foliage was all purple on a delicate pink shale. It was a small outcrop but beautiful.

In Pennsylvania I was checking another small deposit and showed evidence of having been burned. While most of the fossil foliage in Pennsylvania is black or black impressed with streaks of white, a small section made a very lasting impression on me because of the very beautiful bright pink color of the background. It reminded me of the fossils that I found in my father-in-law's coal cellar: leaves imprinted on the coal he was burning in the family furnace. The family has never stopped teasing me about collecting fossils in the coal bin.

Back to that piece of pink shale in Montana on the rancher's property. Sam and I sorted and wrapped the specimens that we would haul back home for study and display. They basked in the warm sunshine and made their own music, and we understood why they have been called "clinker shales." We had much to discuss on the long trip back to California.

Pennsylvania's Icy Blue CELESTITE

Collectors Have A Field Day At The Meckley Quarry

by Sandra Downs

For many years, collectors of Pennsylvania minerals have braved the waves of mountain ridges that guard Northumberland County's greatest treasure—the vivid blue celestite crystals found at the Meckley Quarry in Mandata, Pennsylvania. In this sleepy little village, 30 miles north of Harrisburg, high on a ridge above the Susquehanna River, the large limestone quarry holds some of the most exciting crystals in the northeastern United States. Once known as celestine, these strontium sulfate crystals appear in conjunction with calcite and strontianite, and received their type locality name from an occurrence near Bellwood, Pennsylvania, several counties to the west.

On Sept. 20, 1998, I had my first opportunity to visit the Meckley Quarry, meeting up with several groups of fellow Pittsburgh area collectors whom I'd first met while working with them on the

Delicate balls of strontianite (above) nestle amongst celestite and calcite crystals. The 1998 collector's open house at the Meckley Quarry (left) yields a special celestite find (inset) for collector Bob Horn. Calcite crystals (below) often appear in conjunction with celestite and strontianite.

Carnegie Gem & Mineral Show. Collecting lasted from noon until 5 p m My husband, Dave, and I showed up an hour late, finding the parking lot full of cars. Some intrepid souls had traveled from Massachusetts, Texas and Florida for this annual event

Meckley's Limestone Products, established in 1936, has a long reputation of being open to individuals and groups interested in celestite In the early 1990s, an incident of vandalism that accompanied an organized trip closed the quarry to all collectors. Fortunately, the owners forgave the trespass, and in 1997 they established an annual open house To host this event, they do a lot of preparation, targeting the mudstone layers (the Tonoloway formation) that cut through their dolomite. Blasting and peeling away these fractured beds, they spread the piles of assorted rock neatly across the quarry floor, away from the crumbling highwall. Danger zones are well marked with orange cones, any collector crossing into those zones risks losing Meckley's continued goodwill toward the mineral collecting community

Because I was recuperating from pneumonia, I couldn't do much more than sit down on a boulder and look at the rocks around me I took the opportunity to talk to collectors as they walked by. One Meckley employee, there on his day off, showed a pretty serious interest in where folks found their crystals

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Celestite/ *from page 49*

"The best stuff is in the contact zone between the dark limestone and the mud zone," he said. "The vugs form in that contact zone - which is the most dangerous part of this quarry, since it makes the highwall unstable." He noted specific piles from which collectors had pulled crystals, saying, "This is all going in the crasher tomorrow, so you bet I'm going to take a look through it before it does!"

Dave headed to work, looking for those vugs full of crystals. It didn't take long for him to bring a few pieces back for my inspection. Not celestite, but tiny calcite crystals, forming a sparkling drusy skin inside the vug. Their slight blush tinge hinted that celestite might be buried in there somewhere. Another piece contained tiny balls of strontianite best visible through the loupe. Meanwhile, some of my friends started to find the elusive treasures.

"Here's one." Tony Orzano said, and he showed me an excellent crystal a good quarter-inch across. Margaret Robinson brought over some of her tabular celestite crystals for my viewing pleasure.

There is no limitation on bringing children into the quarry (except your signature on the release form and your pledge to look after them), and the kids were everywhere. One young fellow picked up a piece of mudstone and showed it to his dad.

"Dad - look at this! It's like a sandwich." Sure enough, the piece had thin layers of calcite crystals sandwiched between layers of mudstone. Dad deftly broke open the vug using a thin chisel and handed it back to an admiring son.

On the other side of the quarry, a contingent of ill-prepared Girl Scouts had come in from a nearby town. It was their first time collecting minerals. They wore sneakers, had no safety equipment, and carried their parents' carpentry hammers. Ouch! I spoke to the troop leader and explained how she should properly outfit the kids on their next outing - and in the meantime, don't use those hammers if you don't have glasses to protect your eyes! As I walked away, she let out a shout. I turned around, fearing the worst, and saw her waving a rock in the air. Sure enough, as soon as I'd turned my back, she'd flipped over a rock and found long, fat, brush but nearly transparent celestite needles on a drusy calcite. Beginner's luck! The girls began flipping over rocks, a much safer pastime than they had planned.

Not far away, another fellow had a lucky strike that turned out to be the find of the day, so I wandered over to see what he was admiring. He was Bob Horn, vice president of the Clifton (New Jersey) Mineral & Lapidary Society. He'd stumbled across a massive block of crystals. This was his second trip to the Meckley quarry, and a [illegible] indeed.

"I found nothing but calcite the first year I was here," he said. "That made me pretty worried when I got here late, after 1 p.m., and saw all the cars. But I started flipping rocks over in this section, and this popped up!"

"This" was an eye-popping piece with large, dark blue crystals an inch across and twice as long! Word seemed out, and collectors began to gather around Bob to admire the beauty. In addition, he'd found several fractured crystals in the same area, so folks started turning over rocks, looking for broken pieces. A few of them were successful. Dave came back to me with some small bits - enough that we could say we had some Meckley celestite of our own.

Around 4 p.m., the call went out that one of the employees had celestite for sale at his house. If we were willing to drive over to Mandata and take a look. The short drive and steep climb up to his garage turned out to be very fruitful, since it was chock full of flats priced between $5 and $10. A few choice pieces were priced per specimen, but at these dirt-cheap prices we could all drive home with a stunning hand specimen of celestite for our collections and have plenty left over for trade. Nothing on his garage, however, compared to the crystals that Bob Horn found - truly the gem of the day!

Collector Gary Van Gelder shows his son how to open up the mudstone along a crevice.

Planning Your Trip to the Meckley Quarry

The quarry is located along state Route 225, 30 miles north of Harrisburg, Pennsylvania. Follow U.S. 22 north from Interstate 81 at Harrisburg to Route 225. Traveling through the scenic highlands of the Susquehanna River, the road winds up and down steep mountain ridges and through numerous picturesque towns. The main body of the quarry sits on the right side of the road just before you enter Mandata. A longer but faster route: state Route 147 follows the river from the Route 225 intersection at Millersburg to Mandata, turn south on Route 225, and the quarry is about a half mile south of town.

All collectors must sign a release form, there are no exceptions. A nominal fee (usually $1) is charged. Club insurance is not required, and individual collectors are welcome. There is no collecting limit, but you may not drive your car into the quarry.

Required safety equipment includes safety glasses, steel-toed boots and a hard hat. Recommended tools include large and small sledge hammers, chisels, a bucket and a dolly - it's a bit of a trek back to the car!

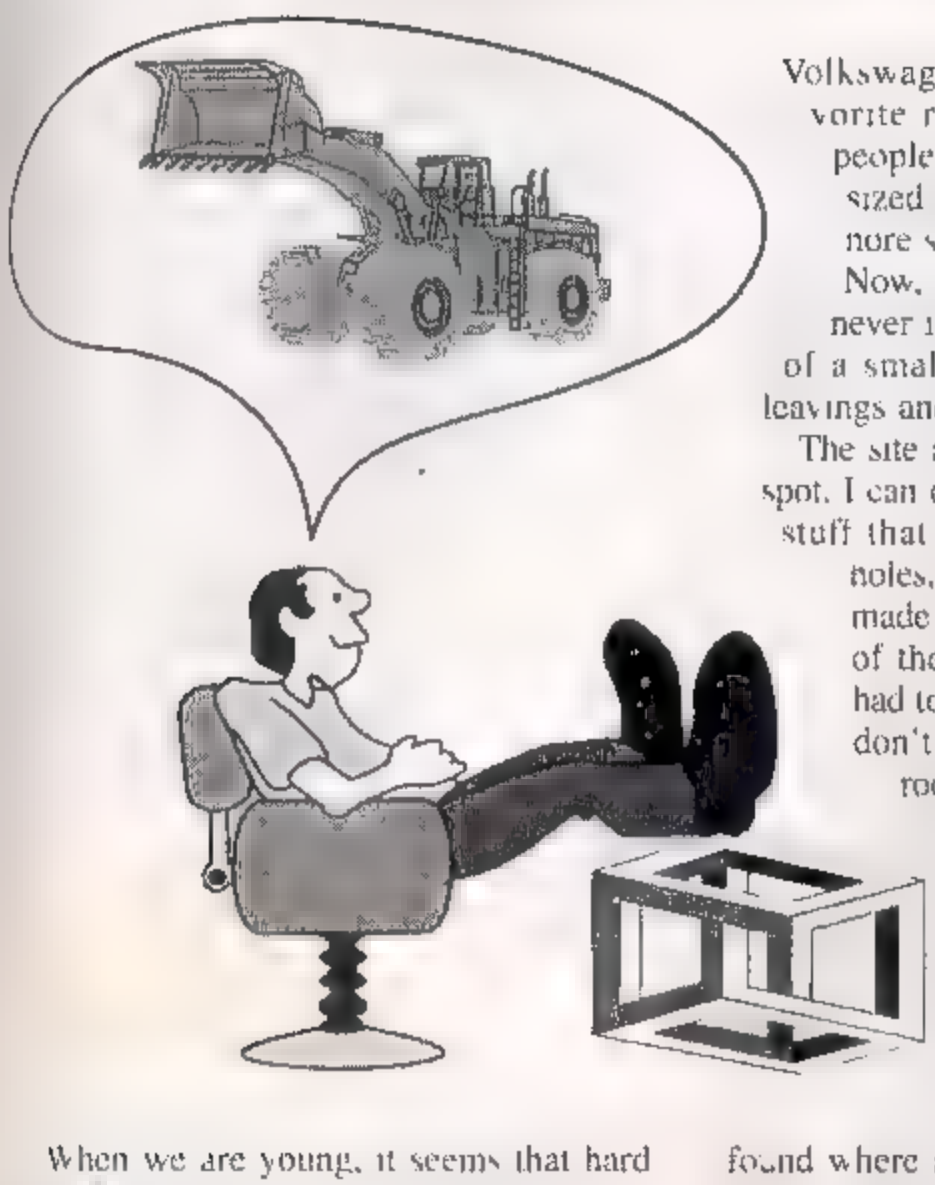
During the 1998 collecting day, the local high school band set up shop on the quarry floor selling cold sodas, pop, snacks and sandwiches. Meckley also places portable toilets near the collecting site. Local mineral collectors may show up with materials to swap or trade from flats in the backs of their trucks.

The 2000 collectors' open house will be held Sept. 17; call (570) 758-3001 for more information.

Shop Talk

by William A. Kappele

HEAVY LIFTING



When we are young, it seems that hard work just comes naturally, but after a few gray hairs appear, it is nice to let someone else do the heavy lifting for a change. It you have been around the hobby for a while, you know that a lot of rockhound ing requires heavy lifting. An old-timer up in Utah once showed me a big, beautiful chunk of red palm wood that he and a friend had dug up. The hole was 20 feet deep before they found it. One man dug while the other hauled up buckets of dirt. Now, I don't think I was ever young enough to work like that, but fortunately for many of us there are those who still do. A lot of the old sites look like bands of super gophers had gone on a rampage. One of these is on Boron Dry Lake in Southern California, and another is near McDermitt in Nevada, way up on the Oregon border. There are lots more all over the country, but these two are typical.

When you come to such a spot, you have a couple of options. First, you can make the assumption that the last person to dig in the hole gave up just inches away from the mother lode. Of course, it may just be that the reason the hole is so deep is that a whole lot of people made the same assumption. The second option is to assume that the last person took home a Volkswagen-sized chunk of your favorite rock. The nice thing about people who aspire to Volkswagen-sized rocks is that they tend to ignore some nice cabochon material. Now, I don't know about you, but I never intend to make a cab the size of a small car, so I just pick up the leavings and head for the grinder.

The site at McDermitt was just such a spot. I can only wonder at the size of the stuff that came out of some of those holes, but I found a lot of wood that made me happy right around the lip of the hole where the "big boys" had tossed them. Thanks, boys, and don't make a bola out of that big rock or you will spend a lot of time looking at your boots.

Another nice spot where the heavy lifting has been done is tract home sites (be sure to get permission). I have a fossil pecten (that's the shell like the one on the Shell Oil sign) that a friend found where a housing development went right through a spot called Pecten Reef. Houses now cover all but a small section of the reef that was saved as a park.

We all know that mine dumps and tailings piles can sometimes be gold mines (no pun intended), but don't overlook the lowly road cut, either. One small cut in our area was so full of fossils that the county had to spray tar on it to keep the fossil hunters from eroding the bank. Cora and I have found a lot of fossils in road cuts all over the place. There are several very productive ones in Colorado, and one in Kentucky that has some of the most beautiful mineral specimens we've ever seen. Just be sure that the area you are in allows hunting in cuts. Some states don't want you there because of the obvious danger to you from traffic and to the traffic from your rolling a boulder down on it.

OK, get out there and look for spots where someone has done the heavy lifting for you, and bring home some treasures the easy way.

Please feel free to contact me if you have a suggestion or comment about this or any of my Shop Talk columns. My e-mail is quappelt@ix.netcom.com, or write to me at 25231 Perdu Drive, Mission Viejo, CA 92691.

SUMAS MOUNTAIN FOSSILS

Sister Mountains Share More Than A Name

by Peter Thorne

Rising abruptly above the flat flood plain of British Columbia's Fraser River Valley is the solitary 2,979-foot Sumas Mountain. Located 50 miles east of Vancouver, and on the east side of the town of Abbotsford, the isolated mountain is home to subtropical plant fossils dating from the late Paleocene Epoch through the Eocene.

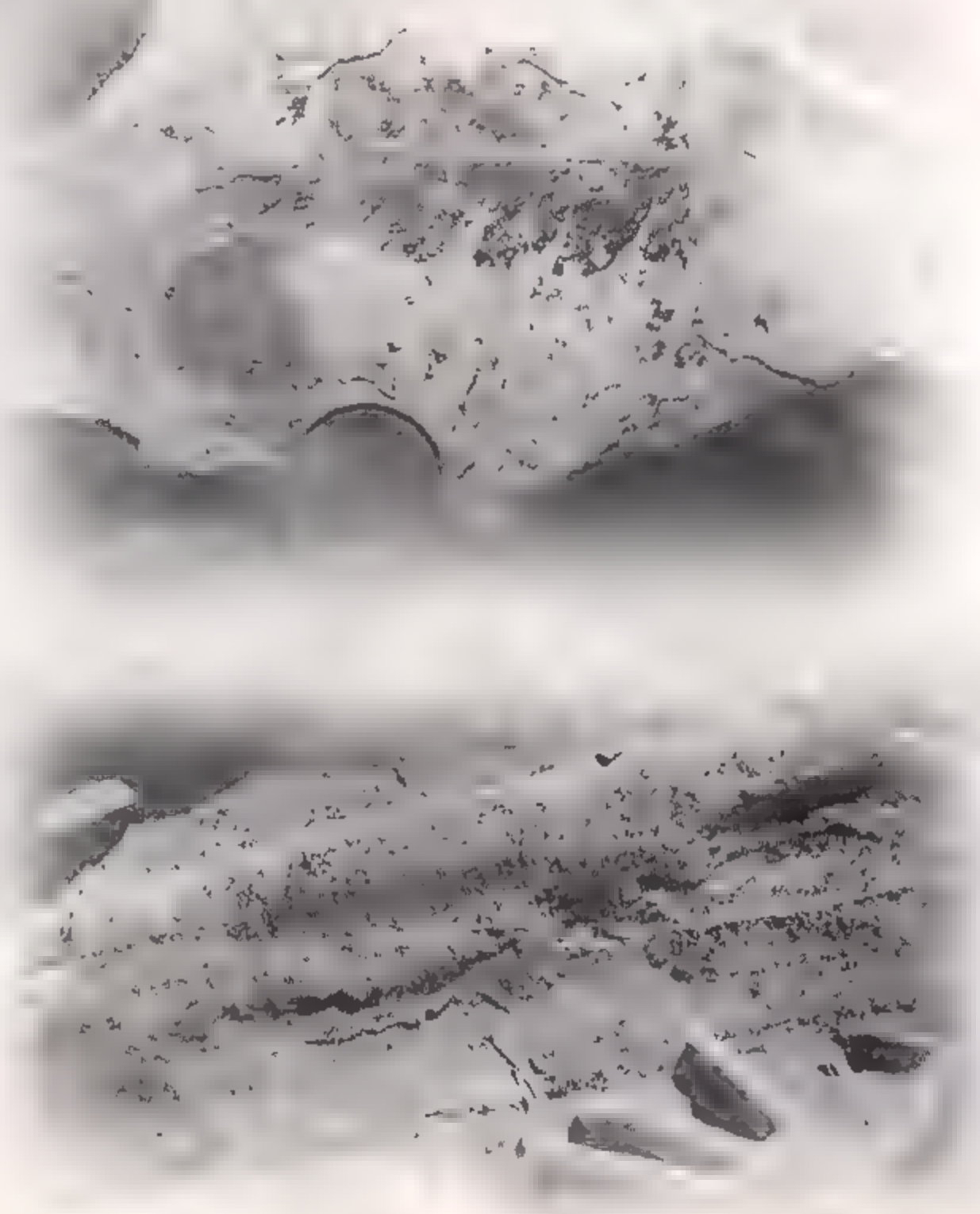
The fossil-bearing shales to be found on Sumas Mountain are near the eastern edge of an oval-shaped sedimentary basin extending into the United States to south of Bellingham, Washington. These fossiliferous sediments are part of the Huntingdon Formation.

Sumas Mountain is a scant six miles north of the U.S. border. Less than 10 miles to the south in Whatcom County, Washington, is another Sumas Mountain, American Sumas Mountain.

The ages and compositions of the two Sumas mountains are considered approximately equal, based not only on fossils, but also on the presence of kaolinite clay layers (fire clay). The American Sumas Mountain deposits of fire clay are the largest in Whatcom County, and have been mined intermittently in the 20th century.

The sediments making these shales, conglomerates and sandstones on both mountains were all put down in fresh water by meandering and braided streams coming from the north and east.

Eocene broadleaf plant fossils are often found in the Huntingdon Formation shales of Canadian Sumas Mountain (left). This fossil fern (below) and the section of flattened trunk or limb (bottom) were taken from the Clayburn Quarry



The Canadian Sumas Mountain shales are commercially mined in the quarries of two different companies. The shale is soft and not well indurated or turned to stone. It has been suggested that the deposits have never been buried very deeply since they were first laid down in Eocene times.

For most of the 20th century, the soft shales of the mountain have been ground into clay for the manufacture of bricks and tile products, including ornamental flower pots. Bricks made of the Canadian Sumas Mountain shale also were used to make homes for the early workers of the quarries. These homes can still be seen today in the small community of Clayburn at the west foot of the mountain.

Although not common on Sumas Mountain, fossil plant leaves, usually as fragments, show that the shales and sandstones originated in a warmer climate than is found there today.

Other fossils from Sumas Mountain and elsewhere in the Huntingdon Formation include pollen and spores from plants dating from the late Paleocene to the early Oligocene, along with the pollen from ferns, conifers and broadleaf trees such as oak, alder and birch. Other plant fossils are the remains of fruit. This includes fruiting bodies and microfossil remains of filamental threads which are considered a useful dating and correlation element.

Clinker Shale/ *from page 45*

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"In about 100 feet, we came to a blast of heat and a crack in the ground through which we could see fire. Flames were licking at the edges, and it was surprisingly hot. We knew that we had to be careful or we might drop out of sight forever.

"We decided to go back to the car and toss our bedrolls on the ground and take a nap. When we awoke, it was dark and the beds looked like the lights of a great city with flames here and there. We walked with great care, as we didn't want to fall into this cauldron of fire. One crack was about 18 inches wide, but it ran for about a half mile, with flames licking at the surface all the way.

"When we decided to leave, we began to worry about getting lost on this vast country with just the ruts to guide the way. We watched every minute to be sure that we stayed the course to the main road. This was one night we would long remember."

When Sam finished his story, I realized that he was suggesting that these shales had been part of the burning coal bed. Of course, I wanted to learn more about these events and the transformation of rocks. This became an entrancing idea as I studied the formation of the layers of the earth.

How do these beds of coal catch fire? There are numerous theories, and the one most often suggested is that the fire was started by lightning. Spontaneous combustion is considered to be the most likely, as coal is combustible. When a stream cuts through a bed of coal and creates a ravine, exposing the coal seam to the atmosphere where there is a good supply of oxygen, the coal will catch fire more readily.

A fast-cutting stream may break the coal into pieces small enough that the sunlight can generate enough heat to ignite a fire. Western coal is generally of the lignite or subbituminous kind, and will ignite at much lower temperatures than the harder coals. When combustion starts at the surface and spreads, it may allow channels to form where gases can accumulate and in time the crust may collapse and allow more oxygen to enter and fuel the fire.

The greater part of the original sediments are of shale and sandstone. When they are subjected to the heat from a burning coal bed, they will generally turn pink or red in color. The pink is caused by minute scales of hematite and the degree of metamorphism. Some beds are formed of mottled colors, which are thought to be caused by a very high temperature.

I saw one strata in Utah where the bed had burned for about 200 feet, but the rest of the coal bed was unaffected, possibly for the lack of oxygen. Erosion had stripped away the covering of the strata, and the sight was dramatic.

Rocks within a few feet of the top of a coal bed may be fused, while those beyond may be baked, and those further on may be only slightly reddened. It is interesting to note that some of the sediments may retain their original texture while others will only be slightly affected.

Both physical and chemical factors are responsible for spontaneous combustion. The coal that is highest in volatile matter, moisture and sulphur is generally the most likely to ignite, or an outcrop of lignite that is exposed to the hot rays of the sun will ignite more readily than unexposed coal. I thought it interesting to learn that some of the burned-out layers were left as magnetite.

I am particularly interested in rocks from the Pleistocene Epoch, and have observed from a distance the buttes in Montana and North Dakota, whose banks of red coloration show where coal beds have at one time been burned. Close examination of these deposits will usually lead you to find some fossil plants.

Many other locations have burned out coal beds. In my explorations I have discovered burned shales in California, Oklahoma, Pennsylvania, Utah, Wyoming, Texas and Nova Scotia. Look at the shales that are metamorphosed around a coal mine to discover some marsh fossils.

I was once told that a deposit in Texas was only black shale of the Carboniferous Period. I was also told that it was called the Red Dog Formation which I have not been able to confirm. However, I discovered a small section of shale that had been burned, and the preservation of the plant foliage was all purple on a delicate pink shale. It was a small outcrop but beautiful.

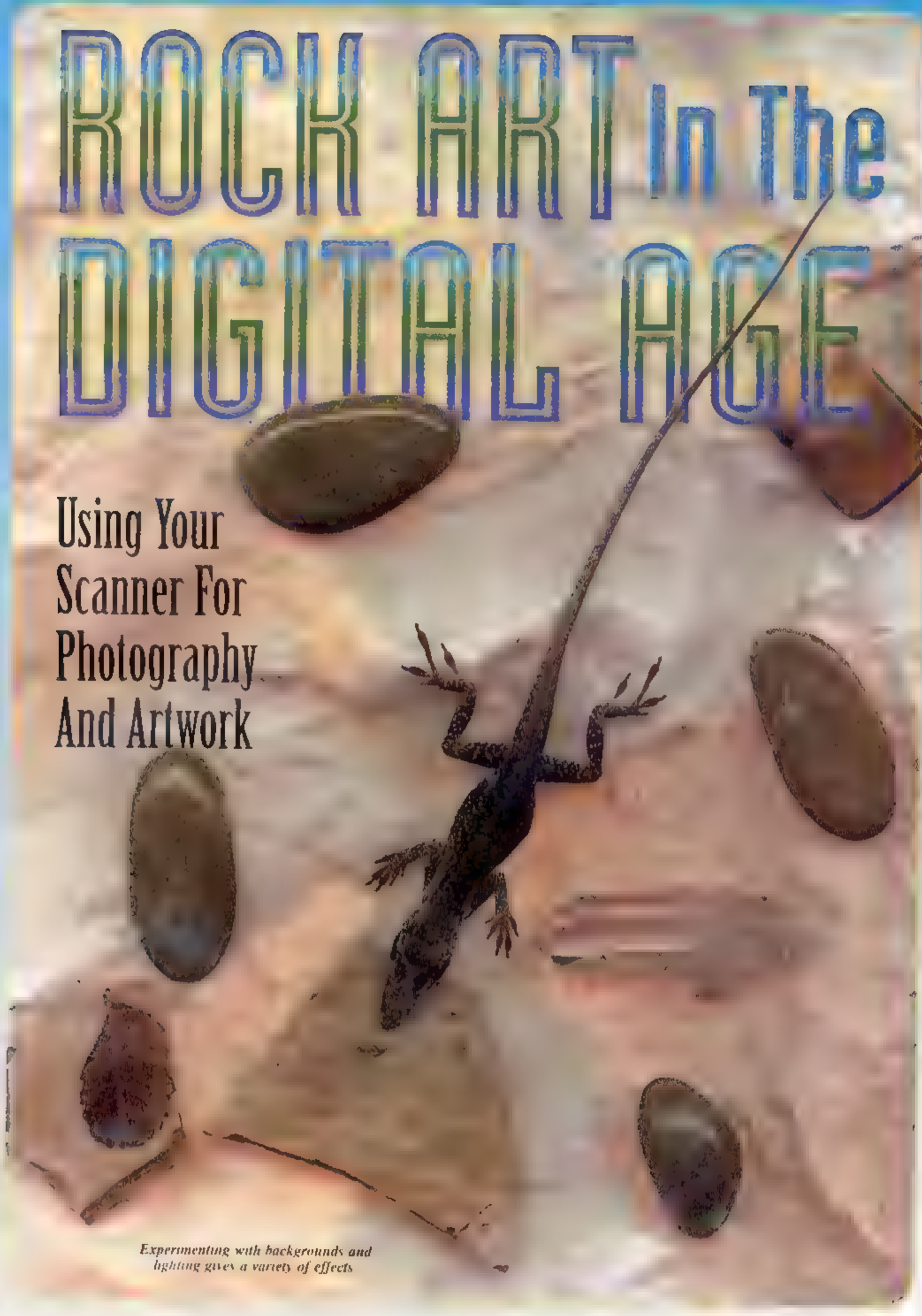
In Pennsylvania, I was checking another small deposit that showed evidence of having been burned. While most of the fossil foliage in Pennsylvania is black on black unless encrusted with calcite of white, a small section made a very striking impression on me because of the very beautiful bright pink color of the background. It reminded me of the fossils that I found in my father-in-law's coal cellar: leaves imprinted on the coal he was burning in the family furnace. The family has never stopped teasing me about collecting fossils in the coal bin.

Back to that pile of pink shale in Montana on the rancher's property. Sam and I sorted and wrapped the specimens that we would take back home for study and display. They tinkled in the warm sunshine and made their own music, and we understood why they have been called "clinker shales." We had much to discuss on our long trip back to California.

The baked material produces a musical tinkle when struck, earning it the nickname "clinker shale."

ROCK ART In The DIGITAL AGE

Using Your Scanner For Photography And Artwork



Experimenting with backgrounds and lighting gives a variety of effects

Scans of fossils show just as much detail of the object as a photograph, or more, with a pleasing three-dimensional effect.

by Terrell William Proctor

In my younger days I occasionally got into trouble with my parents for taking things apart to see how they worked and for dragging things home to study. All my life, I've collected things, to observe, analyze and see what I could do with them. Recently, my lifetime of being inquisitive has paid off big time.

I discovered the magic in my scanner through my regular vocation. To make a living, I am an attorney at law. In connection with my law practice, I received discovery documents from other attorneys that have to be retyped, answered and returned. In order to reduce the work in doing this, I purchased a Hewlett-Packard (HP) 5100C Scanjet "flat bed" scanner, and some optical character recognition (OCR) software, for the purpose of scanning documents. I also started scanning photographs of wrecked vehicles and bruised people, from accident cases I was handling, to store in the computer for future use. I started learning how to enlarge pictures and use programs in connection with the scanned images.

All of this was working out pretty well, although the OCR software took longer than I had hoped for. Photographs were turning out really well when scanned, and I could manipulate them to make larger-size prints for courtroom use. I started scanning some professional photos of some of my artwork from past years. The results were outstanding, and I was getting good comments from beta prints and e-mails sent to friends and family.

My original understanding of a "flat bed" scanner was that you laid flat things flat on the bed (or glass), shut the scanner cover flat, gave directions to the scanner on how you wanted it to scan the flat item, clicked for it to start scanning, and then you got a flat image to store in the computer for future use. I originally assumed that was all a scanner did. It would only scan things that were *flat*.

Two of my avocations are paleontology and rockhounding. I have served as the Cu-

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Rock Art/ *from page 65*

rator and Board Chairman of the Proctor Museum of Natural Science since I and five family members started the museum and incorporated years ago Another avocation is art I do pretty well in creating artwork, and in 1984 I was nominated by a Texas state senator, as one of about 2 for the honor of being named the legislature's Texas Artist of the Year The reason for mentioning these things is to lead into the purpose of this article After reading about and seeing some of the scanned images which are printed with this article I believe you will be inspired to use your own scanner for "photography" without film, to create what I call, "eArt"

While using my HP scanner for the intended purposes, somewhere along the line my curiosity kicked in The scanning of photographs was turning out fantastic results While my scanner was proving to be a boon for what I bought it for, I was soon to learn it had "magic" beyond my dreams

For the benefit of readers who may be somewhat new to scanning, let me cover a little about scanner usage and terminology "Resolution" is a term that refers to the number of dots per inch (dpi) or pixels in a scanned image If the resolution is 300 dpi, that means that each inch contains 300 pixels or dots of color. Each dot is composed of a mixture of the three primary colors, plus black (computers and scanners now are referred to as having 256 colors or a much higher alternative, running into virtually unlimited color, depending upon your computer and scanner)

Therefore, if an item you have scanned at 300 dpi is to be saved to cover say, an area of 7 inches wide by 9 inches high when printed out or sent electronically, the image size would be said to be 2,100 pixels by 2,700 pixels (7 inches X 300 dpi 2,100 and 9 inches X 300 dpi = 2,700) If you scanned the same item using a 150 dpi setting and wanted the same size image stored, then the image size in pixels would be one-half of that at 300 pixels (1,050 pixels by 1,350 pixels

With most scanning software prior to scanning a document, you can select various settings, in addition to the number of dpi, you want to use to scan the item The normal default setting is 150 dpi, which is used for documents, normal photos and other scanning I recommend scanning at 300 dpi fossils, minerals, artwork and other things you wish to have high resolution It gives you a better final image when printed out However, in creating Web sites, it is recommend you scan at only 72 dpi, because high resolution scans lengthen the time needed to load a Web site, and the higher resolution probably doesn't add that much more to the Web picture

One of the options you have is what size percentage to use in your scan You can elect to scan at 100 percent, which is what usually use, or at more or less than 100 percent of the actual size This depends on (a) the size of the item to be scanned and (b) what size you want the final image to be when transmitted or stored Since stored photo images and scans take up a lot of space, there are several tricks I've learned to save hard-drive space There are a number of formats in which a computer program may save images Generally, you will see the format as a .bmp or a .jpg extension following the file name The .bmp format takes up many kilobytes (Kbytes) of space on your hard drive If you open that same image file again and save it a second time as a .jpg, whether it was a .bmp file or already a .jpg file, you will find that the number of Kbytes drops dramatically It is not unusual for the number of Kbytes originally used up by a .bmp file to drop to 10 percent of that number when you save it as a .jpg file Even saving it the second time as a .jpg file will drop the number of Kbytes of hard-drive space needed to a small percentage of the original

Another tip is to get a ZIP drive ZIP drives come in 100 megabyte (Mbyte) and 250 Mbyte sizes The 100 Mbyte disk stores the equivalent of about 80 of the old 44 Movie floppy disks The ZIP disks pop in and out easily and load up easily, so they are great

For the moment, let's leave the computer type details behind, because I want to tell you about the really exciting moment I had with my scanner, when I realized that I could use it for more than just flat scanning

For several months prior to my discovery, I had been scanning my many photographs from really good field trips such as in July 1998 to Arkansas for Mississippian Asterosoma fossil brown algae and beautiful quartz crystals, December 1998 and March 1999 to the Leisey Shell Pit in Ruskin, Florida, for Pleistocene fossil mammals and shells, and June 1999 to Harrison, Nebraska, for Oligocene Oreodont and Titanothere fossils I was getting more and more excited about the ability to store these great photographs on the computer, then to make overhead projector slides, enlarge the photos and print them out, and do other creative things with them.

During one of the periodic auctions held by the Paleo Section of the Houston Gem & Mineral Society (HGMS), I had purchased a really good Jurassic fossil fish from Solennhofen, Germany Looking at the fish one day, I realized that it was flat in the matrix My curiosity was piqued as to whether I might be able to scan the fish on the flat bed of the scanner So I gave it a try, hoping that the slight unevenness of the matrix would not distort the fish too badly To my amazement the slight unevenness made no difference, and the scan came out beautifully In fact, it looked better than any photograph I had ever taken of a fossil.

With this initial success, I could hardly

was to start scanning other things. Little by little, I increased the size of items scanned, as I tested the distance from the bed that would allow me to get a good scan of the item. I found that the scanner didn't care if things lay flat on the glass bed or not. The scanner was not just a flat bed scanner at all, but actually acted as a camera and was taking excellent photos of things as high as four inches away from the bed.

The only problem I encountered at that time was that the farther the distance an item was from the bed of the scanner, the less light reached it and, therefore, it got darker. While the fossil or mineral image was good, the background was turning out to be a dark, muggy green. I had successfully scanned an Oreodont skull, which was about 4 inches high. (The Oreodont was a browsing animal of the Oligocene, about the size of a collie or sheep. This skull had been found by my friend Duanne Clark, near Harrison, Nebraska, on our June 1999 trip.) It was good, but the very dark background took away from it greatly. On a few items, such as a Pleistocene llama leg bone from Leisey Shell Pit, the scanner would only give a black and white scan. Again, I experimented. I took two day-glo orange dots, stuck them back to back and laid them on the glass. Voila! the scanner now scanned in color, the bone's dark brown now showed its true color.

Although the fossil and mineral scans were coming along great, the dark background was ruining a lot of them. What to do about this? I had a ring stand on hand, along with both a 95 watt incandescent work light and a fluorescent work light. I put the ring stand next to the scanner and attached both lights to it, so that I could move them up and down over the scanner bed or swing them out to the side. Then the lid of the scanner came off, so that there was nothing over the bed but the lights.

After my trip to Arkansas, I was trying to identify the Mississippian brown algae fossils. The Librarian of the Paleo Section of HGMS sent me a printout from a Web site identifying the fossils. I contacted the owner of the site, J. Michael Howard, who is the state geologist for the Arkansas Geological Commission. Mike, in turn, steered me to John David McFarland, the paleontologist for the AGC, who exchanged e-mail with me over the fossils. Then we talked about scanning, and I learned that John had used some Kleenex over fossils he scanned, and got good results. Using this idea, I tore the edges of several Kleenex so that they didn't have sharp edges, but blended together for an artistically appealing effect. I laid some tuberous begonias on the bed, used the Kleenex over them and got a nice effect. Because the Kleenex sheets were too small to use only one, the folds in them couldn't be smoothed out very easily, and the machined impressions in the Kleenex somewhat gave away what the background was. Therefore, I needed something similar without those problems.

By now, my creative juices were flowing. It just so happened that I had brought in some clothes from the cleaners. The shop I use always stuffs large pieces of tissue up the sleeves to make them look round. I pulled one of these large tissues out and rolled it into a very tight ball, which made the tissue crinkle up a great deal. Then I flattened the tissue back out and smoothed it with my hands so it was relatively flat again.

Next, I started laying out things to scan on the scanner. I laid out fossils, minerals and flowers, and eventually even made a scan of my own face. In each instance I laid the crinkled up tissue or a piece of cloth over the item to be scanned, with one or both of the lights turned on above during the scan. Since I am single, starting the scanner and having time to plop my head on the scanner bed, cover it with tissue and keep my eyes open with a silly grin on my face while I got scanned was no easy task.

Each time, the scanned item came out really great (OK, we won't count my face), and appeared to be floating before the lovely crinkled background of the tissue. Recently, Deifiah, my lady friend from Florida, was so impressed with the flower eArt scans I had done that she insisted on buying 10 copies of one of the scans that she especially liked to take back to Florida to mat, frame and sell as artwork. I was flattered at this interest, as I had offered to give her the 10 eArt scans printed on photographic paper without charge. However, she insisted on paying me for them and thinks she can develop a market for my eArt work. That would be nice, of course.)

I have also uploaded eArt scans of fossils, minerals, flowers and some insects to the Internet for friends and family members. The responses have been most enthusiastic. Most say that the items look better than if photographed, that there is more of a three-dimensional effect than a photo gives. Deifiah is only one of the people who tell me that they have had the downloaded eArt mailed and framed to hang in their homes.

To me, the ability to not only list our fossils, minerals, cabs, gemstones and faceted items in a book, but to now be able to store an actual image of each item in the collection in a computer-generated catalog greatly increases the value of the collection and enhances each item in it. It also provides much greater protection in case of theft or casualty loss, for insurance purposes and for purposes of recovery by identification.

In short, this new technique has been an outstanding success. John David McFarland tells me he refers to scans as "images" since there is no official name we know of for this process at this time. I have given it the name of eArt in my communications

continued on next page

with others and in articles. To me, eArt appears three-dimensional. Although I have taken many thousands of pictures over the years, I have never taken a photograph with a camera that looks as good as a scan does. It's just a super new media to work with.

Without a doubt, I'm not the only person who has discovered how to use a flat bed scanner to do three-dimensional scanning. However, to date, I have not seen anything written about it anywhere else. I wanted to share with you this wonderful discovery and all I have learned thus far about the technique of using the scanner as a camera and a tool for creating art.

A couple of months back, I presented my early results from using the scanner for storing fossils to the Paleo Section of HGMS. Most of the members appeared amazed that they could use their own flat bed scanners to start taking "photos" of their fossils without a camera and film, as I had learned to do. The March 2000 issue of the HGMS publication, *BackBenders Gazette*, carried my story about this procedure. This was followed by a similar article I had written, which appeared in the April 2000 issue of the publication of the Tampa Bay Fossil Club, called the *Chronicles*. Mike Howard, the Arkansas state geologist, tells me that he will put a similar article about the procedure on his Web site as soon as I get it to him. And by the way, Mike has a wonderful Web site for rockhounding in Arkansas, at http://www.rockhoundingar.com, thanks to the creative talent of his wife, Darcy, who creates Web sites for people.

I've incorporated many of my eArt scans into the Web site for the Proctor Museum of Natural Science, which is at http://www.ProctorMuseum.org.

Finally, let me give you some more technical information to assist you as you start using your scanner for photography and artwork. In doing my eArt scans, I sometimes use only the fluorescent light, at other times only the incandescent light, and sometimes both. The fluorescent light alone gives a light-green or chartreuse background. The incandescent light alone gives an orange or yellow background. On other occasions, I use both, and depending upon the height and placement, it gives from a pale beige to a yellowish light. I also try raising and lowering the lights in different combinations, and placing them directly over the bed or pulling them out to the side to get different effects. Soon, I intend to experiment with different colors of tissue, different colors of lights and other combinations not yet dreamed up. You won't need to use the day glo dot when scanning as long as the lights are on, because the scanner has never produced black-and-white images again since I started using the overhead lights. Sometimes I use cloth instead of the tissue.

Software programs also can change things a good bit. Some programs will let you turn your eArt into a vignette by feathering out the four corners to leave an oval or round effect around the item scanned, or by using feathering to make the edges soft and to fade into the image, instead of having a hard border edge. I've also learned that sometimes the lights from the scanner will glare on a glassy object, and give off a white streak with a maroon edge on one side and green on the other. You can use a painting program to paint out the glare, by mixing colors to match those of the object on either side of the glare, then using a computer brush or spray can to carefully paint out the glare, dark background or other part of the scan you want to change. You can change the entire background with a click of a button in the computer, and make other big changes. The ability to work with your eArt image after you complete your scan, using the many programs available for your computer, is simply amazing.

Another pointer. The results you get also will depend a great deal upon what you print your eArt scan on. If you use plain photocopy paper, it will look pretty good and cost very little. If you use the various brands of premium inkjet paper, your scan will look good, and cost only slightly more. If you use HP or Kodak or another good brand of premium photo paper, your scan will print out beautifully. Fifty sheets of premium photo paper will cost you between $30 and $40, or less than $1 per sheet, including the ink. Avery offers a six pack of "textured canvas" for inkjet printers for about $9 to $10, if you want to have your eArt scan look like an oil painting.

There are other products by various manufacturers. At Office Depot and other stores, you can get 10 sheets of Canon media to print your eArt scan out on, then press it onto your own T-shirt. Pretty neat, having your own mineral or fossil find on the T-shirt you wear to the next Gem & Mineral Club meeting, huh? There also are note cards and envelopes on which you can print out your eArt scans, along with brochure size and folded papers.

Another important point in working with your scanner, computer and printer, along with uploading to the Net or e-mailing. It has taken a good bit of experimenting, but I have learned some things about how many pixels to use for various purposes. When I do an eArt scan, I do several "saves" of the same scan. I do one at 650 pixels wide for when I want to send it with e-mail, as that's just about as many pixels, at 300 dpi, as you can use and stay within the parameters of the e-mail edges. For printing out copies onto a full 8½-by-11 inch sheet, I store the scan at about 1,800 pixels (6 inches @ 300 dpi) to 2,100 pixels (7 inches @ 300 dpi) and, on occasion, at as much as 2,400 pixels (8 inches @ 300 dpi)—but sometimes this last choice proves too large and nothing will print out.

For working on eArt scans, I usually use CorelPhotoHouse (which comes with WordPerfect 9.0 Office or VuePrint). I have other software, however, I prefer using these two programs at present.

When saving images, make sure that the height in pixels is not going to exceed the height of the page you're printing on. If you had a relatively narrow image and you decided to make it a good bit wide to fill the space, you could make the height so tall that it would not all go on one page. Your final product would print out with parts of your image on two pages. You can usually click back and forth between inches and pixels to see your width and height in both units of measurement.

In doing the fine work, I have found that my Logitech mouse, which is a great product for what I normally use it for, makes it difficult to work with the paint brush or spray can on the screen without getting too much where I don't want it. I understand that there is a stylus available which simulates painting on canvas. That is now on my "want list" of things for my computer. I use an HP 722C Deskjet Printer, and my scanner and color printer each cost me about $300—pretty cheap compared with the results I get and what I have spent in past years for computer equipment.

In conclusion, if you own a computer and are an avid rockhound and/or paleontologist, get yourself a good, but inexpensive, flat bed scanner and color printer. Then start using these scanning techniques to store eArt scans of your fossils, minerals, flowers, gemstones, artifacts and other important finds from those field trips. You can put them into newsletters, Web sites, slide-show presentations on your computer, and many other things such as artistic prints to give to friends to frame and hang on your wall. Enjoy the admiration and envy of your friends and colleagues who will marvel at your creative work. I hope this information will help you as you travel down the road in your "Rocky Life."

Terrell William "Terry" Proctor, J.D. is a 65-year-old attorney, mediator and former judge from Houston, Texas. He was a founder and has been the board chairman and curator of the Proctor Museum of Natural Science in Houston, Texas for 11 years. He is a former chairman of the Paleontology Section of the Houston Gem & Mineral Society, 1997 show chairman and twice first vice-president of HGMS. He also is a member of the Tampa Bay, Florida, Fossil Club. Write him c/o T. W. Proctor & Associates, 630 Uvalde Road, Houston, Texas 77015-3766. Phone (713) 453-8338 or (800) 472-5721, fax (713) 453-3232 or e-mail auraman@swbell.net."

Rock Science

by Steve Voynick

Azurite And Malachite And The Copper Age

Besides being eye-catching and highly collectible minerals, azurite and malachite have a special claim to fame. They were the minerals that led man out of the Stone Age.

We may never know whether man first collected gold or copper. Archaeologists have recovered crude, hammered amulets of both metals at European and Asian cultural sites that date to 10,000 B.C.

Gold, copper, lead and tin all occur freely in nature, in alluvial gravels and mineralized outcrops, but only gold and copper have colors that would have attracted the eye and interest of Stone Age man. Gold, with its great malleability and gleaming sunlike color, was certainly the more appealing metal. Although copper also has a pleasing reddish hue, it is not nearly as malleable. Nevertheless, unlike gold, hammered copper was hard enough to have utilitarian value as simple tools. The relative rarity of metallic copper, however, delayed further advances in metalworking technology for thousands of years.

Copper is generally emplaced in the form of such sulfide minerals as bornite, chalcocite and chalcopyrite. When erosion exposes copper sulfide deposits, the action of atmosphere and water oxidizes the sulfides to cuprite, a copper oxide, and to the brightly colored carbonates azurite and malachite. Further chemical action may eventually reduce part of the carbonates to metallic copper. The carbonates, however, were always far more abundant than native copper. Late Stone Age men collected most of their copper from outcrops in which the metal was closely associated with azurite and malachite.

By 5000 B.C. some Asian cultures were already melting native copper in drafted charcoal fires and using crude molds to cast the molten metal into various shapes. At one of the monumental turning points in the prehistory of technology, an early metallurgist, either by chance or by choice, happened to heat not metallic copper but its associated minerals azurite and malachite, in a bed of drafted, glowing coals. The combination of intense heat and direct contact with carbon in the coals, along with free atmospheric oxygen, drove off the carbon and oxygen within the carbonates, leaving behind a small pool of molten, metallic copper. Modern metallurgists describe this reaction as simple reduction smelting.

Few discoveries have ever had greater significance. The realization that copper could be derived from certain colorful, easily identifiable rocks that had no metallic appearance whatsoever represented a quantum leap in man's understanding of the natural world. The technology of crude smelting greatly increased the supply of copper, which in turn lifted man out of the Stone Age and into the Copper Age.

Chronologically, the term "Copper Age," the period when a culture's tools and weapons were made primarily of copper, is of strictly regional value, since the metal came into use at radically different times in various parts of the world. The same is true for the subsequent Bronze Age.

Bronzes, alloys of copper and smaller amounts of tin, were first produced in Southeast Asia about 4500 B.C., possibly by an accidental mixing of copper and bronze ores. Early metalworkers found that bronze was harder than copper and had superior casting qualities, ideal attributes for fashioning improved tools and weapons.

Copper smelting later provided the knowledge to master another metal, iron. Although iron and steels soon became the world's most used metals, copper and bronze continued to have numerous applications. In the 1700s, metallurgists used zinc from central European mines to produce brass, an alloy of copper and zinc that was generally similar to bronze, but much cheaper.

The Age of Electricity that began in the late 1800s was in effect a second Copper Age. No other affordable metal matched the electrical conductivity of copper or was available in the huge amounts necessary to manufacture the millions of miles of cable and wire needed to electrify the world.

So azurite and malachite are more than just collectible minerals. Our entire, 7,000-year-long succession of technological advancement in metallurgy began when some Asian metallurgist, for unknown reasons, decided to heat those two colorful copper carbonates in a drafted charcoal fire.

Calcite has more than 600 crystal forms

An imbalance of electrical forces can cause calcite to curve.

Crazy Calcites

One of the most famous underground occurrences of calcite formations is Carlsbad Caverns in New Mexico.

A bird's nest, formed by mineral-charged water dripping into sand.

Some calcites can't decide which way to grow.

They Do More Than Form Crystals

by Bob Jones

One of the minerals you see in collections almost as often as quartz is the calcium carbonate mineral calcite. It forms in a fascinating variety of crystals centered on the hexagonal/trigonal form. Some of its crystals are pointed, hence the term "dog tooth." Others form in six-sided crystals that have blunt or rhombohedral terminations. Still others form in box-like crystals that look like they are leaning into the wind. I could go on and on, since calcite has the greatest number of crystal forms—an amazing 600-plus. No other species approaches that number. The remarkable thing about this common mineral is that it also goes beyond recognizable crystal forms and develops some really weird noncrystal shapes.

Some of the odd shapes I've seen are corkscrew, completely circular doughnut forms, hooks and soda straws. It seems that some calcites go schizophrenic, throw out all the rules of crystallography, and do their own thing.

Where do you find these calcites that have lost their sense of direction and are so malformed and totally devoid of any outward orderly, geometric form? I say "outward," because even in its most random form calcite, like any crystalline mineral, still has that orderly molecular and crystalline structure within itself. Otherwise, it would not be what it is. It would be an amorphous mineral, and calcite is far from being that.

Maybe the answer to this crazy departure from the orderly world of crystals has to do with where they have formed. These corkscrews, spirals and other odd calcite shapes form best in total darkness, deep underground in caves, where they are born, grow and die. A visit to famous caves like Carlsbad Caverns reveals a hint of what caves can hold. Such a gloomy environment would bring out schizoid tendencies in any respectable organism. But calcites are gregarious! Yet, when you talk to spelunkers, they speak of caves that are "living" and caves that are "dead." If caves are the best place to find these oddball calcites, what does happen to them to make them differ so dramatically from the world of orderly crystal appearance?

Like humans, as calcites grow, they are influenced by outside forces. In caves, the forces that can affect the growth of minerals range from the supply of water to how highly charged with dissolved minerals it may be, to the direction of flow of that water. Even the gentle, almost imperceptible air currents that can exist in a cave can have an effect on the painfully slow growth of cave formations. Then there is gravity. It would seem to be the most important influence of all—and it generally is. But it's amazing how some crystals defy gravity absolutely and grow up, not down, sideways, back and forth, even zigzag, like a lightning bolt. You name an odd form, and calcite has probably emulated it. No wonder we call these "crazy calcites."

Since these strange calcites form in caves, some understanding of those stygian depths is needed. Though I'm not an expert on caves and have only visited a handful here in the United States, Mexico and Europe, I've seen oddly shaped formations time and time again. Many are the calcium sulfate gypsum variety selenite. Rarely, some are another calcium carbonate, aragonite. But the best seem to me to be calcite oddities, for they are perhaps the most unusual.

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Calcites/ *from page 73*

The best "crazy" calcites I've seen have come from the limestone caves that have formed in the Bisbee copper-producing area in southeast Arizona. Here, huge limestone deposits have been invaded by watery solutions, which have etched and dissolved their way through the limestone, carrying away the white rock to form huge cavities and caverns. Later, mineral rich solutions invaded these porous Mule Mountains, depositing marvelous copper species that formed one of the richest sources of copper species in the United Sates. Nature never rests! The limestone continued to be dissolved, only to re form as stalactites, stalagmites, stone curtains and draperies, and some of the most fascinating calcite oddities to be found.

The ore deposit at Bisbee is a remarkable assemblage. The source of the huge variety of copper species is actually a porphyritic ore body from deep within the earth that intruded into the vast limestone formations. As the copper porphyry slowly weathered, it released its copper content to supply surface waters, which carried its treasure into the surrounding limestone.

Though a discussion of all the copper treasures here — malachite, azurite, cuprite and more than 300 different and distinct species — is enlightening, it was the later ground waters that enabled the limestone to contribute its calcium carbonate and under proper conditions, deposited a lovely assortment of cave formations, including our crazy calcites. Some formations were richly tinted with green copper salts. But where surface water lacked any copper ions, it percolated into the limestone cave formation and formed tantly tinted or snow white cave formations.

Certainly, the lack of copper ions did not inhibit the development of calcite deposits. On a trip underground, I saw lovely white flows of calcite covering the walls of very old mine tunnels and even older limestone caverns. But the real calcite treasure here developed where cave growths grew in all sorts of odd forms, influenced by the forces already mentioned. Some developed in mushroom-like stems rounded on top of a narrower base. Still other calcites grew in slender, steadlike crystalline forms, without any sense of direction. Some ended up as complete loops. Others grew in wormlike, curving, pencil thin growths. Some formed zigzag patterns, starting to grow in one direction, then, for no obvious reason, shooting off in a different direction.

It may be difficult to accept how crystal growth can be so strangely influenced by what appear to be subtle forces. For example, many caves have prevailing air currents that are so subtle as to seem ineffective. Yet, the gentle push the movement of air gives is such that, as a calcite growth builds, it may be constantly pushed in one direction, developing a perpetual lean. But suppose the prevailing air current suddenly changes direction due to an internal collapse in a chamber or a new opening developing at the surface? The airflow and the growing calcite both change direction. Now, as the available solution brings in fresh molecules, the growth direction changes.

Moving air also causes water to evaporate, of course, and in this case more molecules of calcite are deposited on the side nearest the direction of air movement. This subtle but inevitable accumulation influences growth direction. In other words, air blowing from the left, for example, would cause deposits to fall on the right side.

More likely, flowing water is a greater influence than is moving air. After all, the moving solution has the necessary mineral content to promote growth, and can exert greater pressure than can air. Often, mineral laden waters rise and fall over the course of a year. When they rise, the growing calcite may thicken because of a greater availability of building material. During a dry spell, there may be little or no growth, and the crystalline forms ends up with a weird thick thin structure.

Even more interesting is the calcite that begins to grow in a solution in a perfectly normal way, but then the depth of the solution stabilizes, losing moisture at nearly the same rate as it gains fresh solution. The result is that the formation stops growing up and begins to grow out like an umbrella, or a stem with a calcite "flower" resting atop it.

What I fail to understand are those strangest of all calcite forms that curve so dramatically that they actually curve right back into themselves. There are other minerals that do this, usually in

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microscopic size. Pyrite is one such mineral. I suspect this is the result of too rapid a deposition of molecules along one edge of the growth. This builds up one side faster than the opposite side, and a curve results. This can happen when there is an imbalance of electrical forces in the crystal field, as more molecules are attracted to one surface at the expense of the other.

Still another oddity with calcite is the development of two different crystal forms within the same crystal. As seen on examples from a number of deposits in Germany, Mexico, England and elsewhere, one crystal form of calcite will develop, then quite suddenly an entirely new calcite crystal form will begin to grow. The famous mineralogist James Dana recognized this in his 11th edition book, *System of Mineralogy*, into which he inserted a drawing of a small calcite crystal from the Bristol, Connecticut copper mine. The specimen is still in the Yale University collection. It is a small, scalenohedral crystal topped by a modified rhombohedral crystal. This is a very common occurrence in calcite. And you might wonder how it can happen.

Calcite crystal growth, like that of other minerals, is strongly influenced by two factors: temperature and pressure. When the solution temperature is relatively cool, as in caves and in ore beds that are later weathered, very simple crystals like the rhomb and the scalenohedron form. But if the temperature of the solution increases dramatically, more complex crystal forms emerge. Pressure can play a similar role.

Still another factor that enters into this equation of odd and varied crystal shapes and forms is the impurities that may affect crystal growth. Water, the great dissolver, carries all sorts of elements, compounds and radicals into an ore deposit. The atomic or molecular size of all these impurities varies, as does the electrical condition. Sometimes, a molecule that is slightly larger than the molecule normally a part of the growth is still able to plug into the developing atomic structure as an impurity. This distorts the growth, and can cause a twisting, a bending, a curving or some other form of distortion. The result is another odd crystal.

Without doubt, calcite is one of the more fascinating and complex mineral species to study and collect. But keep in mind the more than 600 crystal forms it demonstrates. Add to that the growth oddities you'll encounter as you collect calcite, and be prepared to get into a lifetime pursuit, one that will twist and turn in as many different directions as do these crazy calcites, yet another wonder of nature.

Deconstructing SKARNS

Tailings from the Shamrock Mine in the Tungsten Hills include pyrite, calcite, garnet and pyroxene.

The Shamrock Mine's skarn gets its color from the silicate minerals garnet, pyroxene, epidote and quartz.

Magma And Marble Meet To Form An Array Of Metamorphic Rocks

by Roger McPherson

As I was entering the science building at the University of Alaska at Fairbanks, I saw my geology professor unloading flat cardboard boxes from his car. When I offered to help, he filled my arms with four of the boxes. Inside the lab tables were already overflowing with more stacks of the stuff.

"No, not mega pizza for everyone," Professor Rainer Newberry announced. "This is drill core from a tungsten skarn near Bishop, California." He looked in several boxes before selecting one for discussion. "Gather around," he directed us. Holding up a thin rock cylinder of drill core, he surveyed the assembled would-be geologists. "Garth, what do you see in this?" We all relaxed while tall Garth unwound himself from his seat and examined the dusty core.

"Rusty, heavy. Greens and reds." An agonized pause. "Garnets, pyroxene?"

"Pre-cisely!" Newberry beamed. "And look at all the massive pyrites. Typical skarn mineralogy. Your lab assignment is to choose a drill hole and log the core. Each box has five rows, representing a total of 10 feet." A quick count of the boxes showed 50 to 100 feet of core from

each hole. "Your job is to sketch the changes from the granite contact through the garnet-pyroxene zone to the unaltered marble front. Estimate the tungsten grade, mark the faults and note any other sulfides present."

He raced to the chalkboard and began his lecture on skarns. Newberry was Mr. Skarn himself, having published numerous papers on the subject and conducted field trips to skarns most of his teaching life.

"When high-temperature magmatic fluids come into contact with carbonate rocks, all kinds of things happen," he began. "Diagnostic minerals are massive amounts of garnet and pyroxene—reds and greens. Other names for skarns are contact metamorphic and pyrometasomatic deposits, and tactites." He paused as if letting us in on a secret. "Skarns can show up three kilometers from the parent pluton. And they come in an amazing variety: copper, tin, moly, iron, tungsten, lead-zinc and gold."

I had visited the Mount Hamilton gold skarn near Austin, Nevada, before it closed because of the low grade of the gold. Located high on the steep face of a range front, the deposit had been created at the edge of a large granite stock. Rock hammers bounced off the hardened and hornfelsed skarn. Sharp rocks tore up the heavy equipment tires and caused maintenance problems. Much of the deposit was in wollastonite, a white, granular mineral formed by the alteration of marble into a calc-silicate. Boulders of light green pyroxene added some color to the open cut, but with gold concentrations in the one part per million range, shiny sulfides were the only visible mineralization.

Newberry had suites of rocks from the different types of skarns for us to place in their order of formation and distance from the magma. A high-temperature mineral such as molybdenite is commonly located closer to the igneous rock, while other minerals are deposited at lower temperatures farther away. Scheelite, a calcium tungstate, is precipitated by reaction of tungsten-bearing fluid with marble or limestone, and it tends to be concentrated at the marble front or disseminated in the garnet or pyroxene zones.

For two weeks we sketched our observations of mineralization in the small cylindrical cores on sheets of paper, noting changes from massive garnet to pyroxene to wollastonite to marble. Graduate students circulated to offer help. Garth was kidded mercilessly about missing the pyrites in the core: "Hey, Garth, what's this heavy stuff that's kinda rusty?"

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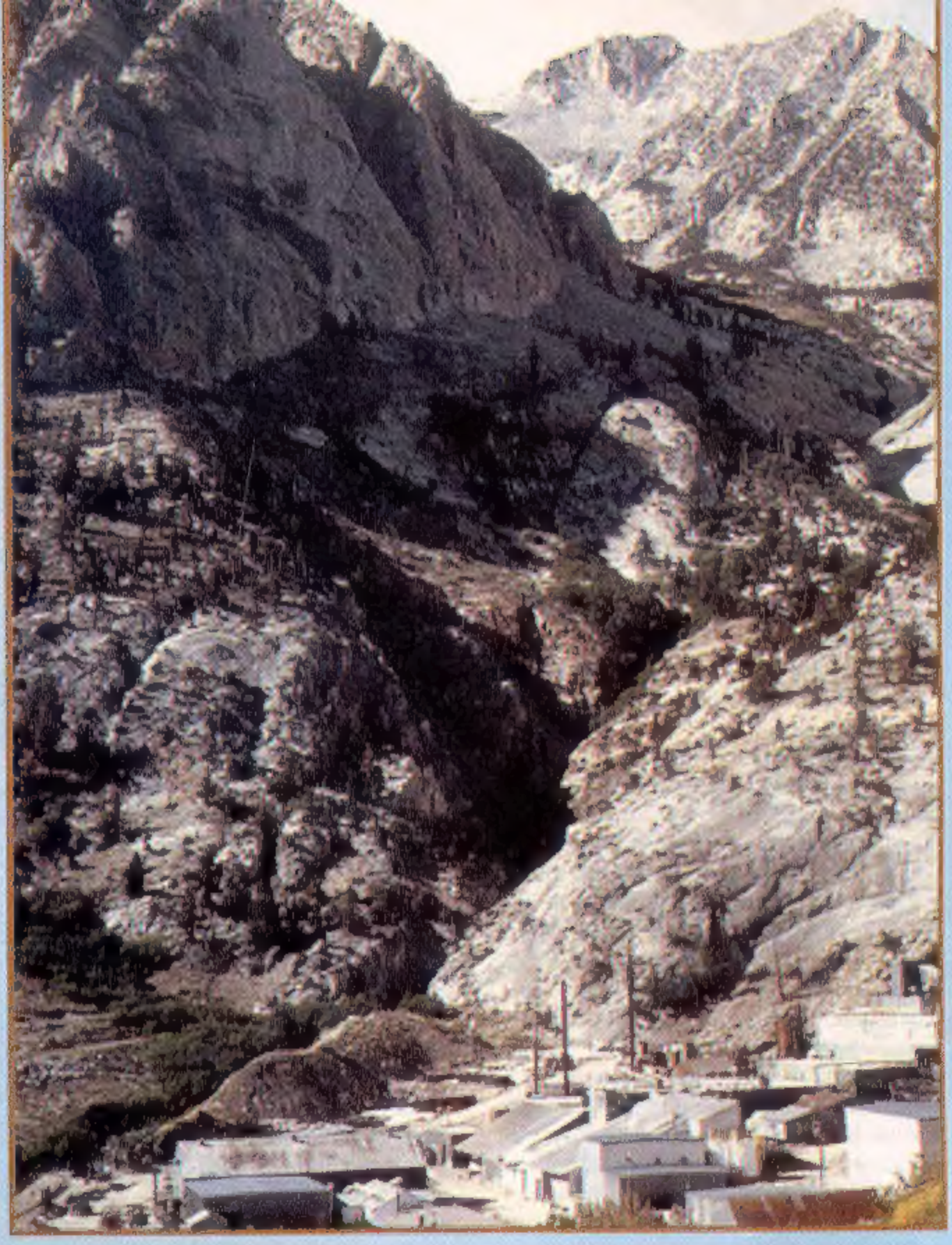

The Pine Creek mill now processes tungsten from China, Peru and Portugal; the mine is no longer worked.

The Black Rock mill ruins, and the mine, on the hillside behind. The best skarn silicate minerals can be found here.

Skarns/ *from page 81*

The graduate students shook their heads at the monotonous core. "Use your hydrochloric acid," they'd say when asked about a questionable area. "If it fizzes, it's the marble front. If it doesn't, it's been altered to wollastonite." We all spent time with boxes of core in a dark room, passing the UV light over them, noting white flecks of scheelite and estimating the grade of the deposit.

When the time came to turn in the lab reports, half the class was missing, perhaps burned out from the assignment. The analysis had been difficult, and no one was sure they'd done it right. Skarns aren't fun in the field; they are erratic and have to be carefully mapped. Logging drill core is one of those tedious tasks geologists do to bring order to the subsurface geology.

The first skarn I examined was at the Spruce Hen tungsten claim near Fairbanks. As an exercise, my UAF Mining Extension teacher, Jim Madonna, had us map the open cut. At one end of the shallow, open pit, a wooden headframe squatted over a dark hole in the ground. During the two world wars and the Korean War, tungsten prospects had enjoyed a brief importance. Now, no one seemed to care much about the mine, and it was abandoned. We mapped a narrow zone of garnet, pyroxene and dark-green epidote crystals that hosted the tungsten. A thin bed of limestone had been totally replaced by these colorful calc-silicates. However, under a UV lamp, the low-grade specimens showed only a few flecks of scheelite.

I had always wanted to visit the Bishop tungsten mines, located in the Owens Valley of California. When I approached Professor Newberry about my trip there, he pulled out the California Division of Mines Special Report 47, "Economic Geology of the Bishop Tungsten District" (1956), and Special Report 48, "Economic Geology of the Casa Diablo Mountain Quadrangle" (1956), and pointed out his favorite places. Northwest of Bishop were the Tungsten Hills, with glory holes at Deep Canyon and at the Round Valley Mine. West of Round Valley, the famous Pine Creek Mine was located in the steep Sierra Nevada Mountains, and to the northeast, off U.S. Highway 6, near Benton Hot Springs, he told me, the Black Rock Mine presented a magnificent view of its contact zone, spread across a mountainside.

"I wish I could go with you," Newberry admitted. He waved his hands in the air. "You'll see these huge roof pendants of metamorphic rocks in the Sierra batholith. Mega contact zones."

"And big piles of specimens?" I asked.

"Pre-cisely!"

Typical skarn rocks at the Round Valley tungsten mine, containing calc-silicates of pyroxene and garnet.

I drove south from Reno along scenic Highway 395. On one side, the deeply furrowed east slope of the Sierra Nevada Mountains swept upward, while the pungent sagebrush hills of the basin and range spread out to the east. I had often backpacked into the Sierra Nevada from this side, puffing up endless switchback trails to reach granite-bound lakes with their resident cutthroat trout. The bare ribs of the granite batholith that forms the core of the Sierra Nevada are exposed in the high, rounded mountains enclosing the Donner, Tahoe, Carson and Tioga Pass highways. In places, metamorphic rocks were isolated and surrounded by the granitic magma as it worked its way upward. Uplift and erosion has removed most of the overlying beds to reveal miles of light-colored granite, with only a few remnants of the older metamorphic rocks.

Near Bishop is the Pine Creek Pendant, a metamorphic mass of marble, schist and quartzite that hosts the tungsten mines of the area. Also near Bishop is the Round Valley septum, a smaller island of metamorphic rocks in the Tungsten Hills, where additional mines are located. Marble, called "lime" by miners and prospectors because it consists of recrystallized limestone, makes up the most important ingredient in the formation of tungsten deposits. The California Division of Mines Special Report 47 on the Bishop area states, "The universal requisite for the presence of a tungsten skarn is the juxtaposition of calcareous and granite rock—a clean calcareous marble and a light-colored granite."

Beds of white to blue-gray marble up to 3,000 feet thick are found in the islands of metamorphic rocks in this area. Contact with the granitic melt created skarn, an old Swedish term for the associated silicate minerals: light-brown to reddish garnet, grayish-green pyroxene, olive-green epidote and quartz. In addition to the silicates, minerals such as fluorite, idocrase, amphibole, calcite, wollastonite, zoisite and feldspar were formed. White to yellowish or pale olive scheelite was disseminated within the skarn or in rich ore shoots, and other metamorphic beds of schist, quartzite and impure marble had been transformed into a hard, dense rock known as hornfels when they contacted the hot magma.

The tungsten mines had their greatest production during the first and second world wars and were brought to life again during the Korean War. The Pine Creek Mine, which was operated by Union Carbide's U.S. Vanadium Company, then by Strategic Minerals' U.S. Tungsten, and more recently by Avocet Tungsten (see "The Upside-Down Mine," by Joseph Kurtak, *Rock & Gem*, December 1997), is the largest deposit in the region and the most productive in the United States. It's located 18 miles northwest of Bishop, California, at the end of Pine Creek Road.

By 1953, the Pine Creek Mine had produced $88 million worth of tungsten, along with significant molybdenum and copper. The ore bodies outcrop at an altitude of 11,200 to 11,900 feet, and the deepest workings are at 8,130 feet. The mill at the head of Pine Creek used flotation separation, and gravity and chemical processes, to obtain scheelite, molybdenum and copper. The scheelite occurs as finely disseminated grains, which fluoresce white to yellow, indicating some powellite, a calcium molybdate, in the

scheelite. The main ore body averages 500 feet long and 75 feet wide over a vertical distance of almost 3,100 feet.

I stopped at the Millpond Campground just north of Bishop and met Bill Curtis and his wife, campground hosts. Dressed in faded blue jeans and a shirt with pearl snaps, Bill sat in the shade in front of their trailer and told me about life at the mine.

"I came into the valley in 1949. It was 24 hours a day, seven days a week then. I had numerous jobs at the mill—batch mix, digestors, presses. Worked on the bull gang—that's the laborers. I mainly drove trucks hauling dirt, and worked on the roads going up to the mine." He paused to light a cigarette. "They had a couple of snow slides that took out their garage and some of the mill. It's a very avalanche-prone area. Zero-Level was where I was going in when I began work. A-Level was right on top of the mountain. There's miles and miles of tunnel in that mountain. I've heard guys say it took them two hours to get where they was working." He shook his head at the memories. "The early Shirley Temple Mine is up there. It burned down. It was one of the things her dad spent her money on. It never really got off the ground."

I drove up Pine Creek Canyon the next morning just as the sun began illuminating the Wheeler Crest, a sheer face of Sierra granite named for Lieutenant George Wheeler, head of the United States Topographical Survey of this area in the 1870s and 1880s. Aspen along the creek were turning golden, and a few hikers were at the trailhead below the mine, adjusting their packs for the long series of switchbacks ahead.

Avocet Tungsten's chief geologist at the mine, Brian Norris, a tall, thin man wearing an orange hard hat, took me through fluorescent-lit offices to a meeting room with wooden captain's chairs. "I've worked in skarns for 21 years," he told me. After a short search in a dark closet, he presented me with a small, but very heavy, rock. "It's loaded with tungsten. Typical andradite garnet, pyroxene and calc-silicates." He took me through a few empty offices. Timesheet holders had the names of past employees: Ken, Rudy, Hans, Ray. "We're down to 19 on staff," Norris noted. "The company laid off over 30 people last week."

Chinese tungsten production has flooded the market. The Pine Creek mill processes material from other countries, including China, rather than mining deep in the mountain here, and Avocet Ventures, a London-based company, shipped in concentrates from tungsten mines in Peru and Portugal. Inactive since 1991, the Pine Creek Mine has large reserves that could be developed if the demand for tungsten increases.

Joseph Kurtak's book *Mine in the Sky*, a history of the Pine Creek Mine that includes personal recollections of some of its miners, can be ordered from the author at 5621 Whispering Spruce Drive, Anchorage, Alaska 99516 for $20, plus $3 postage. The many photos and personal accounts in the book show his family's long experience with the mine. His father, Ray Kurtak, was mill superintendent, and he developed processes that are still used today.

Eight miles west of Bishop are the Tungsten Hills, sited at a lower elevation and more accessible than the Pine Creek deposits. Gold placers on the south side of the hills, in Deep Canyon, contained a heavy white metal in the concentrates that was identified as scheelite. After an 18-month search, a prospector found the scheelite in an outcrop of garnet where he'd shot a jackrabbit—hence, the name Jackrabbit Mine, which dates to 1913. The town site of Tungsten City was laid out nearby, but was never developed.

Tungsten Hills mines are grouped around the Deep Canyon (Tungsten City) area and the Round Valley Mine, the oldest and most productive in the hills. Around Deep Canyon are the Jackrabbit, Little Sister, Aeroplane (the first to produce ore in 1916) and Tungsten Blue (Shamrock) mines. On the north side of the hills, the Round Valley Mine began production in 1917. Near the Round Valley Mine are the Western Tungsten Mine and Tungsten Hill Mine. These all had open pits, as well as some underground workings.

Both sides of the Tungsten Hills can be reached by using Ed Powers Road, four miles north of Bishop. Shortly after turning west off Highway 395, I turned right on South Round Valley Road, passed the Millpond County Park and Campground, and, about four miles after the turnoff, located the Owens Valley Conservation Camp. A dirt road led around behind the camp, and I stopped near a back gate rather than continue on through a sandy-looking wash. A one-mile hike brought me to the Round Mountain and Western Tungsten mines' green-and-red open pits on the hillside. A metal building at the foot of the hill contained drill core from an extensive drilling program by Inspiration Mining, and their company drill roads zigzagged across the hillside. There were plenty of light-colored skarn rocks on the dumps and in the pit walls.

To visit the east side of the Tungsten Hills, I followed Ed Powers Road, driving one mile west from Highway 395 to Tungsten City Road. The wide dirt road went two-and-a-half miles into Deep Canyon before climbing up to the mines. I parked when the road began to climb, because four-wheel drive is needed to get up the steep mountain roads. Hiking up to the Shamrock Mine, I found skarn loaded with iron pyrites littering the track. This skarn and the open pit with tunnels leading into the mountain were heavily iron-stained. Many of the hills around this area have old glory holes with colorful specimens of skarn.

"Don't miss the Black Rock Mine," Professor Newberry had told me. So, to complete my trip to the area, I drove 16 miles north of Bishop on U.S. Highway 6 to Benton Station, then two miles west on U.S. Highway 120 to Benton Hot Springs. I stopped at the tree-shaded store and asked directions to the mine. I also made the best decision of the day when I asked about having a soak later. "I'll fix up a tub for you," Bob, the owner, assured me.

From the hot springs, I took Yellowjacket Road south, and within a mile it turned to well-graded gravel. After eight miles of gravel, it joined an old paved road (unmarked, but named the Black Rock Mine Road) that went one mile west to the mill site in the shadow of the mine. In 1917, scheelite was discovered here, and by 1928 production began. During 1953, it was the sixth-largest tungsten producer in the United States. Now there are four large, open cuts near the top of the mountain and more than a mile of underground workings.

After parking near the abandoned mill, I gathered hammer, sample bags, water and a picnic dinner in my packsack and began to hike. Flooding had washed out the lower part of the road to the mine, so I crossed the gully on foot and started up the abandoned road. Hiking up a gentle grade, I passed by tunnels and small open cuts, but my goal was the glory hole near the top of the mountain. I heard Professor Newberry's voice whenever I wavered in my resolve: "Black Rock is the best example of skarn. You've got to see it!"

That evening, huge boulders glittering with garnets, deep-green pyroxene and epidote crystals served as my dinner table. I was surrounded by the brightest and deepest-colored silicates I'd ever seen in a skarn. I filled my pack with some of the heavy beauties and descended as alpenglow lit up the mountains with golden light.

Soon, I was soaking in 95-degree mineral water in my own wood-stave tub among the willows and shrubs at Benton Hot Springs, watching the moon and the stars move slowly across the dark sky. I thought about the striking array of colors and minerals I'd seen: scheelite, silver-gray molybdenum, brassy chalcopyrite and pyrite set in a rainbow of garnet, pyroxene and epidote—classic skarn specimens. I owed it all to Professor Newberry—and the unique geology of tungsten deposits in the dry Owens Valley and mountains around Bishop, California.